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THE KENTUCKY AND INDIANA BRIDGE.

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Believing that the above-named structure is of sufficient magnitude to merit description, and the record of the progress and development of the details of the work of sufficient value to be of interest to the profession, the writer submits the following as a correct and tolerably full account of the construction.

The Directors of the new railroad being built between Louisville and St. Louis, *via* Evansville and New Albany, Ind., which was nearing completion in January, 1881, had, at an early stage of the enterprise, considered it expedient, and necessary to the interests of the road, to have a new bridge built crossing the Ohio River at Louisville, giving them a shorter and an independent entrance into the city. They therefore obtained charters in Indiana and Kentucky for such a structure, the former on March 2d, 1875, and the latter on April 1st, 1880.

These gentlemen, with others, formed a stock company, to be known as the Kentucky and Indiana Bridge Company, incorporated under the laws of Kentucky on February 1st, 1881, and of Indiana, March 7th, 1881. The capital stock was, after carefully detailed estimates, placed at $1 500 000.

The general location of the structure having been determined upon as connecting the lower part of the city of Louisville, known as Portland, and the upper part of the city of New Albany, Ind., the Stockholders and Directors appointed Mr. John MacLeod, M. Am. Soc. C. E., of Louisville, as Chief Engineer, and Mr. C. Shaler Smith, M. Am. Soc. C. E., of St. Louis, as Consulting Engineer.

The preliminary surveys of the river were commenced April 10th, 1881, and finished in about two months. These covered shore lines for two miles, sounding and boring, and current observations at three stages of water. The locations of the usual courses of vessels of different kinds crossing the proposed line were determined with the assistance of the chief falls pilot, in order to accommodate the river interests as much as possible in the disposition of spans and location of piers.

A map embodying all the results of surveys, together with the arragement of spans and elevation of grade finally determined upon, was made and forwarded to the War Department for approval.

From gauge records of the Government canal, as to stages of water for different seasons for several previous years, was plotted a hydrograph, which, together with the results of later observations up to completion of bridge is shown by Plate XV. The map of location sent to Washington is shown by Plate XIV.

The original idea of the bridge comprehended a structure capable of accommodating railway and highway traffic, to compete for the former with the upper bridge built by the Louisville Bridge Company—Mr. Albert Fink, Past President Am. Soc. C. E., Chief Engineer ; Louisville Bridge and Iron Company, contractors—now principally owned and operated by the Pennsylvania Railroad; and to supply facilities for the latter which had been but indifferently afforded by the existing ferry.

The site selected is at the narrowest point of the river, and admirably suited to accommodate both cities at its termini, and the railroads expected to run over it.

At this point the difference between extreme low and high water is greater than at any station on the river between Pittsburgh and Paducah, both included.

This difference, according to the data afforded by the great rise of 1832, is 67½ feet, and the Act of Congress providing for the construction of bridges over the Ohio requires that the lowest point of any structure spanning the channels of the river at this point shall be 40 feet above ex-

treme high water, thus necessitating the bottom chord center line to be about one hundred and nine feet above lowest low water.

The river is divided at the line of bridge into two chutes by an island, the Indiana chute being the wide and shallow, or high-water channel, and the Kentucky chute the narrow and deep channel used at low stages of water.

The current in the latter runs at all times with much force, which, together with the fact that very low water forces all traffic through this channel, made it advisable to avoid the use of false-work in erecting the span crossing it.

Close to the Indiana side of the island the bulk of the coal traffic passes, and the lower end of the island is used for a meeting point for the purpose of shifting tows of coal boats.

These facts made a long span necessary at this point, and a system of cantilevers suggested itself as best accommodating the circumstances of the location.

Taking all these governing points into consideration, the arrangement of spans as finally adopted was as shown by Plate XVI. This gives a total length between centers of end piers 2 453 feet. In this length the whole structure between Piers 4 and 9 is a continuous cantilever system 1 843 feet in length, the longest yet constructed, as far as known to the writer.

The design upon which the first estimates were based is shown in skeleton profile in Plate XVI.

The details of the substructure, as specified in contracts, comprehended the excavation of foundations for piers to bed-rock, which consists of limestone overlaid by slate of variable thickness. The stone to be used in the piers to be Bedford oolitic limestone, with courses up to 18 feet above low water, 37 inches in thickness; stretchers not over 8 feet 6 inches long by 3 feet wide; and headers not less than 6 feet long by 3 feet wide. Above this level the courses to vary, with minimum thickness of 2 feet 1 inch. The specifications for stone and for setting the same were rigid, insuring first-class work.

The quarries at Bedford are large and well equipped with channeling machines, and could get out the stone for the thick courses at a cost less than for smaller stone. Hence the bids showed that there was no additional cost, incident to the increased size of stone, in obtaining the material, and it was believed that time might be gained in setting

the stone in the wall and an improvement made in the solidity and appearance of the finished work. Piers 1 and 9 were to be of wrought-iron cylinders filled with concrete.

The superstructure was to be in general outline as already mentioned.

The cantilever system to be of steel in the trusses and iron in floor, and the remaining spans entirely of iron. The floor was to be riveted between trusses.

Unit strains in steel as follows:

Tension in eye-bars	13 500	pounds per square	inch.
Riveted chords in 20-foot lengths	14 000	"	"
Posts, 1.4 times their value in iron.			
Iron parts:			
Eye-bars	10 000	"	"
Posts by adaptation of Rankine's formula.			
Shape-iron tension, net section	10 000	"	"
" compression, gross section	8 000	"	"

Estimates were carefully prepared of quantities and work to be done, and on September 16th, 1881, the Stockholders and Directors of the Bridge Company conferred on the President the authority to call for bids on the work.

The successful bidders were as follows:

Foundations: Peter Scully, St. Louis, Mo.
Stone: Hinsdale Doyle Granite Company, Bedford, Ind.
Freight on stone: Louisville, New Albany and Chicago Railway Company.
Laying masonry: McAtee, Flannery & Cassilly, Louisville, Ky.
Superstructure: Edge Moor Iron Company, Wilmington, Del.

The estimated cost of bridge, based on these bids, was as follows:

Pier 1, cylinder pier	$12 237 87
" 9, "	20 217 23
Piers 2 to 8 inclusive, masonry piers	263 113 00
Total substructure	$295 568 10
" superstructure	719 053 00
Total	$1 014 621 10

Contracts were at once signed with the contractors for the substructure.

Ground was first broken in foundation for Pier 2 October 10th. The excavation was carried to bed-rock and cleared off in three days, the foundation being dry. On October 29th the caisson for Pier 3 was pumped dry and excavation commenced.

Bed-rock was reached at a depth of three feet on November 4th, but the foundation was not completed, as the river began to rise very rapidly, and in a short time the caisson was overflowed and work stopped.

On November 9th the first stone was set at Pier 2, but little was done, however, as the rise in the river soon covered the work.

Much valuable time was lost by the masonry contractors through mismanagement, and the plant being put up by them was inadequate to handle the very large stone in the lower courses. Hence the work was partially taken into the hands of the Bridge Company, and finally the contractors gave it up, and the contract was annulled by mutual consent on December 5th.

During the winter and spring nothing of consequence was done in the river. Stone was received from quarries and unloaded.

The first great rise in the river for many years occurred in February, culminating on the 22d at an elevation of 61 feet above low water.

The spring passed and the water did not subside to a point low enough to reclaim the foundations at Piers 2 and 3, and the only activity about the site was the receiving and unloading of stone.

Complications arose when the signing of traffic contracts with the Louisville, Evansville and St. Louis Railway, and the Louisville, New Albany and Chicago Railway was brought up, the directory of these roads having changed during the interval. Negotiations between the Bridge Company and the railroads not progressing satisfactorily, work was entirely suspended May 15th, 1882, and the contractors so notified.

The work thus stopped was left as follows: Foundations 2 and 3 excavated, but lost in high water; a large amount of stone in yards ready for laying; the entire plant of masonry contractors in possession of Bridge Company by purchase; and the sheets of cylinder iron for Piers 1 and 9 on the ground.

Nothing further was done towards construction until October 10th, 1883, when work was recommenced. Foundation for Pier 2 was reclaimed and stone-setting started. A new caisson for Pier 3 was put in place, being sunk as building progressed until bed-rock was reached. The river rose and drove them out just as it was anchored down. Some excavation was done on shore for Pier 1, and some riveting up of sheets of cylinders.

On December 10th, 1883, the contract for foundations and setting stone was let to Messrs. Bruce & Alexander, of Indiana, who immediately took charge of the plant and went on with the excavation at Pier 1, and commenced sinking the cylinders.

Work was continued with varying success until the great rise of the river in February, 1884, which reached its height on February 16th, at an elevation of 70.6 feet above low water, or four feet higher than ever before known. No damage was done by the rise at the bridge site.

The water subsided rapidly, and on April 14th excavation was recommenced at Pier 1, and from that time the work was prosecuted vigorously whenever the river permitted, until the last stone was set on the last pier July 6th, 1885.

The following is a brief summary of the progress on the various piers in the order of numbers, commencing at the Indiana shore, without reference to their chronological order, the work being necessarily intermittent on any particular pier, inasmuch as it was attempted to bring each in turn above ordinary stage of water as soon as possible after the foundation was obtained, and then proceed to others which were in a less forward state.

CYLINDER PIERS 1 AND 9.—Each pier is composed of two cylinders, 7 feet diameter under coping, with a uniform batter of ½ inch to a foot. The cylinders are formed of wrought-iron sheets ⅜ and ½-inch thick.

The lower or cutting edges are made of segmental castings, 9 inches wide at top, and tapered to an edge at bottom. On the circular shelf thus afforded just inside the shell is laid a 13-inch brick wall extending to the top of cylinder.

The cylinders are completely filled to within 15 inches of the top with hydraulic cement-concrete thoroughly rammed. The proportions of this concrete are, 1 part cement, 2 parts sand, and 6 of broken stone which will pass through a 2½-inch ring. This concrete was put in at Pier 9 with the clam-shell dredge used in excavation, and with funnel-chutes around the edges. Portland cement was used in the concrete for the lower 10 feet of cylinders.

On top of the concrete was set a course of stone projecting two inches out of the cylinders, and on this was set the coping course. By this arrangement no vertical pressure is allowed to come on the wrought-iron shell.

PIER 1.—Work commenced in earnest December 10th, 1883, and was prosecuted until the 25th, when the cylinders struck rock. They were at that time 13 feet high. Nothing further was done till April 14th, 1884, when an order was issued to take them out and set them closer together to accommodate new design of bridge. After hoisting out the cylinders the slate was excavated until the bed-rock was reached and then they were lowered into place, and on May 1st the first cylinder was leveled and brick-laying and concreting commenced. This was continued until May 29th. Nothing more was done until July 9th, when work was carried on ten days and again stopped.

On August 6th the pier was again taken in hand, and on the 23d concreting was finished and the pier left. The coping was set on February 23d, 1885, thus finishing the work on Pier 1.

PIER 9.—Excavation began September 22d, 1884. Work on this pier was carried on steadily, with various discouraging mishaps due partly to the nature of the soil through which the cylinders were sunk, and partly to the insufficiency of the contractor's plant. Excavation was done by aid of pumps in the interior of cylinders. When the water could no longer be kept down a clam-shell dredge was used.

The brick-wall linings were built up continuously as the sinking progressed, giving a sufficient load, in addition to the weight of cylinders, to cause them to sink rapidly when excavation progressed favorably.

The earth around the cylinders was caving in most of the time, due to the running in of the sand on the lower level on the shore side. This caused them to slide and tip slightly, but whenever this occurred it was corrected by jacking the cylinders over during sinking.

The cutting edges struck rock May 12th, and after cleaning off the surface the concreting was rapidly pushed and the cylinders filled, and last stone in coping was set on July 6th, 1885.

River Piers.—These average 9 feet wide by 36 feet long on top under coping, and 106 to 120 feet high, with a batter all around of one-half inch to the foot.

All these are masonry piers resting on rock. Although without ornamental work of any kind, they present an appearance of solidity which, considering their height, is seldom exceeded.

In obtaining the foundations several methods were pursued. On the Indiana side the surface of the bottom was bare, and the strata of limestone on which it was designed to rest the piers dips downward towards the Kentucky side at an angle of about seven degrees with the horizontal.

The limestone is overlaid with thin sheets of slate, until Pier 7 is reached, where it runs out. This slate was easily blasted out, and the surface of the limestone immediately under it proved for a thickness of from ½ to 2 inches nearly as hard as flint.

The sand and gravel overlying the slate commenced at Pier 3 with a thin covering, and increased in depth towards Kentucky, until at Pier 8, 15 feet was encountered.

Pier 2.—As already stated, the foundation for this pier was obtained dry at a low stage of water, nothing but a puddle wall being used at any time in setting the lower courses of stone.

Work on the wall was commenced in earnest May 1st, 1884, and prosecuted vigorously, with few interruptions, until July 11th, when it was ready for coping. The first 40 feet was built with derrick on shore, and then as water rose, use was made of derrick boats for 25 feet more. The remainder was carried on by derrick set on the pier itself, and jacked up as the work progressed.

On July 9th, 1885, the coping course was laid, finishing the pier.

Pier 3.—At this pier the foundation was, as previouly mentioned, nearly finished in 1881, when the rising water filled the caisson.

This caisson was an octagonal box, of 2-inch vertical pine plank thoroughly caulked. Inside rings of 10 by 12-inch timber were placed every four feet in height, braced by oak timber bolted on top horizontally across the corners. The holding-down key-bolts passed through these braces into the rock.

This caisson was entirely lost in the high water of 1882.

A new one was begun October 23d, 1883, in plan also octagonal, of 2-inch plank, but laid flat, with hot pitch between the layers. The lower four feet was of 12-inch-wide plank, next four feet of 10-inch plank, next four feet of 8-inch, and next 6-inch plank, each layer being securely spiked to the one next below. This was jacked down as fast as built, and when finally in place on bottom was bolted securely to rock on outside.

As with the other box, the bottom was no sooner reached and all made secure, than the river rose and drove them out. Nothing more was seen of the caisson until after the great rise of February, 1884. On May 27th it began to show again, and on July 22d the water had subsided enough to work, and pumping was commenced and mud excavated. The next day the first stone was set in this pier.

This work was carried on about two-thirds of the time until November, when it was stopped a few courses below the coping.

During the first week in June, 1885, the pier was finished by setting the last coping stone June 8th.

PIER 4.—This foundation, commenced June 26th, 1884, was put in with a coffer-dam, built as follows:

Two rectangular frames of 12 by 12-inch timber were made, the outside frame about ten feet larger all around than the inside one. These were braced and bolted together in the same horizontal plane. Two other frames were then made, and braced together about four feet apart, of such size that the outside frame was three feet smaller all around than the outside frame of the former pair, and the inside frame three feet larger than the other inside frame.

The last pair was then put in place, ten feet vertically above the first pair and 1½-inch plank sheet piling driven close inside the frames, the space filled with puddle forming a wall ten feet thick at bottom and four feet thick at top. The whole rested on gravel.

No success in pumping dry was obtained until the inside sheet piles were driven to rock.

July 1st high water claimed the dam, but on the 15th day of the same month gave it up, and pumping-out commenced, and excavation was completed and first stone set July 19th. Three feet depth of gravel was encountered, and three feet of slate was blasted out before reaching bed-rock.

Masonry was laid continuously, with a few interruptions, during July and August, and again during November and the first half of December, when the pier was nearly completed.

During the first week in April, 1885, this pier was again taken up, and the last stone set April 9th.

PIER 5.—This foundation was obtained by means of a timber-dam with puddle outside.

The lower four feet of dam was composed of courses of 12 by 12-inch timbers, securely connected with each other by vertical bolts, and the upper section of six feet in similar courses of 10 by 10-inch timber, all being flush on the outside.

July 18th the box was floated into position. Sheet piling was then put in on outside and driven to rock, and puddle placed all around outside of piling. This proved a very satisfactory dam.

August 6th the water rose enough to stop work for ten days, at the end of which time pumping was commenced.

As above stated, puddle was found necessary, and after putting this around the outside on August 17th, excavation proceeded successfully to completion on August 23d, when the first stone was set.

Eighteen inches of gravel and three feet of slate were encountered in this foundation.

Stone-setting progressed fairly well, work being carried on about one-half of the time, until November 5th, when it was stopped for the winter.

On March 13th, 1885, work was again commenced, and continued until April 21st, when the last coping stone was set.

PIER 6.—The foundation for this pier was obtained by the use of an open box framed at site. This was commenced July 31st, 1884, and made 8 feet high, of vertical 1½-inch plank with frames of 12 by 12-inch timber every four feet, to which the planks were spiked and then caulked.

When this was sunk another four-foot section was added, and August 6th work was stopped by the rise of water. During this interval of rest, borings were made to determine how much gravel and rock were

to be encountered. The former proved to be 12 feet in depth and the slate 4 feet.

Excavation commenced August 28th and was prosecuted successfully until September 11th, when it was completed and the first stone set.

Laying stone was pushed vigorously until October 15th, when work was suspended for a month and again prosecuted from November 14th to December 13th. From this time the masonry was carried up in a desultory manner a few days at a time until April 2d, 1885, when the last coping stone was set, completing the pier.

PIER 7.—This foundation was taken in hand by the Bridge Company to insure its completion during the current season.

Two rows of piles were driven 7 feet apart, and 7 feet center to center in the rows. The inside rectangle thus formed was 20 feet wider and 25 feet longer than the proposed dam to be placed inside.

Between the rows were placed wales 2 to 3 feet apart vertically, 6 by 12-inch timber on outside of the inside rectangle of piles and 6 by 10-inch on the inside of outside rectangle.

Three-inch oak sheet piling was then driven close to the wale pieces of the inside row 4 feet into the gravel, and 2 inch planks on the outside wales were driven just enough to penetrate the gravel. This, when completed, left a space between sheet piling 4 feet inside all around, which was then filled with puddle.

The caisson was an open box of vertical 2-inch plank spiked on rectangular frames of 12 by 12-inch timbers placed four feet apart. The bottom frame was in two courses of 12-inch and the others single. The box was first built 8 feet high, and as sinking progressed another section of 7 feet was added.

The space between puddle walls and caisson was 10 feet wide all around, except at the down stream end, which was made 15 feet.

On August 29th, 1884, soundings having been completed, pile-driving commenced, and on September 19th puddle dam was completed. The next day the caisson was put together in place and excavation commenced and pushed night and day until October 8th, when bed-rock was cleared off.

Considerable time was lost from breakage of pumps, but no further delays of consequence occurred, and the ease with which the foundation was obtained confirmed the judgment used in adopting the method followed for this foundation. About fourteen feet of gravel and sand were excavated, and overlying this was a layer of 4 feet of loose rock which had washed down from work done on canal above in 1869. No slate was found.

Masonry was laid continuously from the time the bed-rock was reached for a month, when work was virtually suspended for the winter, the wall extending above ordinary high water.

On April 14th, 1885, work was again started, and continued until May 28th, when the last stone was set.

PIER 8.—The foundation for this pier was put in by the Bridge Company for the same reason as in case of Pier 7.

Owing to expected high water a pneumatic caisson was used to obtain this foundation.

Soundings were taken and borings made with a diamond drill during the first of September, 1884. In October guide piles were driven near the site for platforms.

On November 14th the caisson was launched on the Kentucky shore, and on the 16th it was in place. This caisson was built with vertical

sides 3 feet thick, of 12-inch timbers placed lengthwise. The working chamber was 7 feet high from cutting edges to roof. The latter was 5 feet thick in 12-inch layers; lower course lengthwise, next crosswise, the next two diagonal, and the top course lengthwise.

Posts were framed for open section above the roof, but as the stage of the water allowed work to be pushed without interruption, the masonry could be carried up faster than the caisson was sunk, and the sides were not needed.

On November 20th the bottom floor was knocked out and excavation and stone-setting commenced on the 22d. Sand-blowing was begun and excavation was carried on without serious interruption until rock was struck on the upper end December 4th. The rock was cleared off and the down-stream end of caisson blocked up carefully, and concreting commenced next day.

Laying stone was suspended on the 8th. The filling of the working chamber was completed December 24th, and the air shafts removed and their places filled.

About fifteen feet of gravel and sand were encountered in this foundation, but no slate.

The work, which had been carried on night and day during the sinking and concreting, was now stopped for two weeks until January 9th, 1885, when masonry was laid for a week, and also a week's work was put in during the early part of February, extreme cold weather preventing continuous stone-setting.

On April 23d this pier was again taken in hand, and work progressed continuously until June 6th, when the last stone was set.

Superstructure.

In December, 1883, the final contract for superstructure was executed with Messrs. Charles Macdonald and Edward Hemberle, Members Am. Soc. C. E., on the basis of specifications given in Appendix, and design as shown in skeleton on Plate XVI. The general plans of details were to be furnished from the office of Mr. Hemberle, at Chicago, and the shop work was to be done at the shops of Messrs. Kellogg & Maurice, Members Am. Soc. C. E., at Athens, Pa.

On February 16th, 1885, the writer was directed by the Chief Engineer, Mr. John MacLeod, to assume charge of the work, with general supervision of drawings, bills of material, inspection of material at mills and shops, and of erection, with authority to represent him in all matters of detail.

In accordance with these instructions, the examination of designs was immediately entered upon at Chicago, and all stress sheets and drawings, both general and detail, were thoroughly checked over as regards conformity with specifications and skeleton designs upon which contract was based.

This work was carried on without interruption at Chicago, Buffalo

and Athens until the last pound of material was ordered. No unusual problems presented themselves in course of design, excepting those natural to the system of web members, and the series of cantilever-spans continued to such an unusual extent.

Among the noticeable features of design may be mentioned the use of steel pins 9 inches diameter at pier posts, the size of these posts themselves, which are 30 by 36 inches, using 36-inch steel plates 38 feet long, the largest steel plates ever rolled in American mills. Reference to the stress-sheet tables in the Appendix will also show some sizes which are not often encountered in ordinary bridges.

The entire cantilever system is of steel, with the exception of the floor, which is of iron.

The draw-span and the 240-foot span are composite, iron and steel in the trusses, with iron-floor systems. Early in the prosecution of the work, and as soon as Mr. Hemberle had finished the design of the cantilever system, he disposed of his interest in the contract to the Union Bridge Company, and later Mr. Macdonald also conveyed his interest to them, and from that time the entire contract was in their hands.

In placing the orders for the material, much discrimination was necessary to so scatter it that large quantities might be concentrated at shops simultaneously, so that no unnecessary stoppage might occur due to the delays of mills. In obtaining the iron required this was fairly successful, but in case of the steel prompt deliveries were not the rule. The causes which brought this about, however, were more due to want of duplication and the multiplicity of sizes incident to the design than to the mills.

The orders for steel angles, and bars for tension members, were placed with the Cambria Iron Company. Those for steel plates with Messrs. Carnegie Brothers & Co., who obtained their slabs from the Pennsylvania Steel Company, at Steelton, Pa.

The draw-span was sublet to the New Jersey Steel and Iron Company, who bought their steel billets and rolled their own angles, and had the steel plates from Carnegie's.

No steel-shape iron was used in the work.

By reference to the Appendix a complete record of tests made on the steel used in the structure may be seen, together with accompanying notes as to peculiarities observed, and deductions therefrom, made necessary in course of the prosecution of the work.

In the shops, construction was carried on as vigorously as shipments of material from the mills would allow, and the first shipment of 175 tons finished iron was made to bridge site in May, 1885.

During May and June false-work material was arriving at the river, and in July and August the false-work for 360-foot span was put in. This false-work was about one hundred feet high, and the water was at a very poor boating stage.

September 2d raising was commenced with iron-floor system. Up to this time 410 tons of iron had arrived.

During September 200 tons of steel for this span was received, and October 7–8th raising of the trusses was commenced.

November 12th pile-driving for false-work of Indiana 260-foot cantilever anchorage span was started, and on November 23d the erection of 360-foot span being completed, the 160-foot cantilever arm toward Kentucky was commenced and removal of false-work begun.

On December 3d 140 feet of cantilever was complete, as likewise was the false-work of 260-foot anchorage span. December 15th raising of Indiana cantilever, next 360-foot span, was commenced, also false-work for Kentucky 260-foot anchorage span. December 26th some missing parts required having arrived, erection of Indiana 260-foot span began.

January, 1885, opened cold, but work was pushed as much as possible, and on the 15th pits for sills of false-work of 240-foot Indiana shore span were started. All work in iron-raising was stopped by running ice, January 7th, on account of inability to transfer material barges. Progress was made, however, on both banks of river. On January 18th an iron-hull tug-boat was secured to handle barges, and work resumed on erection, and the 260-foot span was completed next day. The running out of 160-foot cantilever toward 360-foot span was immediately started, and as soon as its length reached 140 feet the other cantilever was resumed and both pushed out simultaneously.

On February 9th the junction was effected without difficulty, the device for adjustment shown by Plate XVII working very satisfactorily.

The Indiana traveler was removed and sent over to the Kentucky anchorage span, and the other traveler was run back to Kentucky cantilever first completed, to be ready to meet the other arm.

Meantime heavy ice had been running, and from the first had gorged somewhat above the false-work of the 260-foot span, giving much anxiety

lest it should be carried out; and that span having during the early ice stage no counterbalancing cantilever on its end, would, from its design, naturally collapse in event of losing the false-work. Immediate attempts were made to stiffen the trusses for such contingency, but the lower works withstood the jamb, being held down by the weight of iron-work.

As soon as safe, after enough weight of cantilever had been attached to the span, the removal of false-work was commenced at anchorage end. The two upper tiers for about one hundred feet had been sent down, when, January 24th, relieved of its superimposed weight, the lower tier for 100 feet rose with the ice and went out in a body and floated down the river erect as when in place. Finally, after floating in a vertical position about two miles, the mass collapsed into individual bents, in which shape the timber was caught some ten miles below.

This might have proved disastrous for the men, who were all over the work, but the slowness and apparent deliberation attending the movements of the false-work gave time for easy escape, which was effected without casualty.

February 12th, false-work for 240-foot shore-span was begun, and on the 17th erection of Kentucky anchorage-span commenced. The latter was completed on the 26th, and cantilever pointing toward Indiana was entered upon. This work was soon stopped, owing to delay in receipt of two eye-bars, and the other cantilever approaching this was projected out as far as possible, and on March 10th its traveler was removed.

On the same day the false-work for 240-foot span was completed and floor-raising was commenced. On the 19th work was again commenced on cantilever.

Rough and cold weather prevented continuous or effective work during the remainder of the month, and the river rose daily, until, on April 10th, it reached an elevation of 158 feet, or but 13 feet below the highest known high-water mark. On this day was celebrated the driving of the last pin of cantilever system, and next day the 240-foot span was swung. As fast as each span had been erected the wood-work of deck and highway, floors and fences, was commenced and pushed rapidly.

The false-work for draw-span between 260-foot Indiana anchorage-span, and 240-foot shore-span, was put in up and down stream, and was finished April 21. Erection then commenced, and was completed May 22d, and on the 26th the span was swung around into line, for the first

time allowing foot passage from shore to shore. June 8th the laying of railroad iron was commenced and finished on the 14th.

On June 21st the bridge was completed, and next day vehicles passed over for the first time. On July 15th the formal test of the structure was made by running over the spans with as nearly the specified loads as possible to obtain, these loads being so placed as to produce the conditions which the original calculations had shown would give the greatest stresses. Deflections were observed by taking sights with Y-levels placed on the piers on level rods held at critical points. These observations were subsequently compared with levels taken after all loads had been removed, and deflections thus ascertained. A record of results obtained will be presented to the Society in a future communication.

The following table gives results of a series of observations taken on the expansion and contraction of the openings in the slip joints marked *b*, Plate XVII, due to effect of temperature. The measurements on the iron were taken at point marked *x* in detail sketch, and for the wood at opening in highway floor just adjacent. The floor is so laid that the sun cannot at any time shine directly on the bottom chord where measurements were taken. A trap-door in the floor was left over every expansion joint to allow examination at any time. The measurements were all carefully taken by same observer, and the same thermometer was used throughout. To obtain the temperature of the iron, the thermometer was laid down, with the bulb resting on the member, out of the sun. The air temperature was also taken under the floor in the shade.

The question of proper amount to allow in slotting stringers and corbels of highway floors, where connected with the iron, was at first a vexátious one, as allowance had to be made for 520 feet. These observations were made by direction of the writer to determine whether the amount allowed was sufficient; and also to learn, if possible, if the movement of the iron under the wood was perfectly free.

As might be anticipated, the expansion shows itself at the openings in sudden slips, and from the results of observations there is little doubt that considereble bending sidewise sometimes occurs, due to friction somewhere before the movement takes place. As a matter of fact the writer has had the slip take place under the rule, being perfectly perceptible, and to the extent of $\frac{1}{32}$ inch.

The results show quite clearly that, owing to circumstances of position of sun with reference to the two trusses, the one expands more or less than the other, and it is also interesting to calculate the difference in deflection of the trusses under the varying circumstances, as may be easily done from the expansions and contractions, as shown in the table. Of course there are some variations from results to be anticipated, but the state of the weather would govern in some cases, and the unknown friction in some others.

The distance between fixed points is 360 feet plus 480 feet, or 840 feet, and the expansion takes place at both points *b*, sometimes more in one and sometimes more in the other, so that only the totals give the absolute expansion for the whole distance between fixed points.

Table of Expansions and Contractions Due to Changes in Temperature.

Time.		East Truss, Ky.		East Truss, Ind.		West Truss, Ky.		West Truss, Ind.		Temp.		Total East Truss		Total West Truss.		
Day, 1886.	Hour.	Iron.	Wood.	Iron.	Wood.	Iron.	Wood.	Iron.	Wood.	Air.	Iron.	Iron.	Wood.	Iron.	Wood.	Weather.
		In.	In.	In.	In.	In.	In.	In.	In.	Deg	Deg	In.	In.	In.	In.	
Aug. 10.	8 A.M.	4	1 7/8	5 9/16	2 5/16	4 3/4	1 7/8	6	2 1/4	84	75	9 9/16	4 3/16	10 1/4	4 1/8	Clear
"	12 M.	3 3/4	1 13/16	5 3/16	1 7/8	4 7/16	1 11/16	5 5/8	2 1/16	97	86	8 15/16	3 11/16	10 1/16	3 3/4	"
"	5 P.M.	3 3/4	1 3/4	5 1/16	1 3/4	4 3/16	1 5/8	5 1/2	2	89	89	8 11/16	3 1/2	9 11/16	3 5/8	"
Aug. 11.	8 A.M.	4	1 3/4	5 1/2	2 1/16	4 9/16	1 3/4	6	2 1/4	82	78	9 1/2	3 13/16	10 9/16	4	"
"	12 M.	3 3/4	1 3/4	5 1/8	1 13/16	4 3/8	1 3/4	5 9/16	2 1/16	95	89	8 7/8	3 9/16	9 15/16	3 13/16	"
"	5 P.M.	3 3/4	1 3/4	5 1/16	1 3/4	4 1/4	1 9/16	5 7/16	2 1/16	90	90	8 11/16	3 1/2	9 11/16	3 5/8	"
Aug. 12.	7.30 A.M.	3 13/16	1 7/8	5 1/2	2 1/8	4 1/2	1 3/4	6 1/16	2 1/4	83	80	9 5/16	4	10 9/16	4	Cloudy.
"	12 M.	3 15/16	1 3/4	5 3/8	1 15/16	4 1/2	1 3/4	5 13/16	2 1/8	90	86	9 5/16	3 11/16	10 5/16	3 7/8	Clear.
"	5.30 P.M.	3 5/8	1 3/4	5 1/16	1 3/4	4 1/4	1 9/16	5 1/2	1 7/8	92	92	8 11/16	3 1/2	9 3/4	3 7/16	"
Aug. 13.	7.30 A.M.	3 15/16	1 13/16	5 1/2	2 1/8	4 1/2	1 3/4	6 1/16	2 1/4	78	74	9 9/16	3 15/16	10 11/16	4	Cloudy.
"	12 M.	4	1 3/4	5 3/8	2 1/16	4 9/16	1 3/4	5 13/16	2 1/16	86	82	9 3/8	3 13/16	10 3/8	3 13/16	Fair.
"	5.15 P.M	3 3/4	1 3/4	5 1/16	1 3/4	4 5/16	1 5/8	5 1/2	1 7/8	91	90	8 13/16	3 1/2	9 13/16	3 1/2	"
Aug. 14.	8 A.M.	3 15/16	1 3/4	5 1/2	1 7/8	4 1/2	1 3/4	5 7/8	2 1/16	84	82	8 1/16	3 3/4	10 3/8	3 11/16	Cloudy.
"	12 M.	3 7/8	1 3/4	5 1/2	1 3/4	4 1/2	1 5/8	5 3/8	2 1/16	99	90	9	3 1/2	10 1/8	3 11/16	Fair.
"	5 P.M.	3 3/4	1 3/4	5 1/4	1 3/4	4 1/4	1 1/2	5 1/2	2 1/16	90	90	9	3 1/4	10 1/4	3 9/16	Cloudy.
Aug. 16.	8 A.M.	3 7/8	1 7/8	5 3/4	1 7/8	5 1/16	1 5/8	5 3/4	2 1/8	91	87	9 1/4	3 3/4	10 13/16	3 3/4	"
"	12 M.	4 1/16	2	5 3/4	1 7/8	5 1/4	1 7/8	6 1/16	2 1/8	94	91	9 11/16	3 7/8	11 5/16	4	Fair.
"	6 P.M	4 1/8	2 1/16	5 7/8	2 1/16	5 3/4	2	6 1/8	2 1/8	97	96	10	4 1/8	11 7/8	4 1/8	Clear.
Aug. 17.	8 A.M.	3 3/4	1 3/4	5 3/8	2	4 7/16	1 1/2	5 7/8	2 1/16	88	82	9 1/8	3 3/4	10 5/16	3 9/16	"
"	2 P.M.	4 1/16	1 7/8	5 7/8	2 1/16	5 1/16	1 7/8	5 3/4	2 1/8	99	94	9 11/16	3 15/16	10 13/16	4	Cloudy.
"	6 P.M.	3 5/8	1 5/8	5 5/8	1 7/8	4 3/8	1 1/2	5 5/8	1 3/4	89	88	9 1/4	3 1/2	10	3 1/4	"
Aug. 18.	8 A.M.	4	1 3/4	5 7/8	1 15/16	5 1/2	1 3/4	6 1/8	2 1/8	74	70	9 7/8	3 11/16	11 5/8	3 7/8	Rain.
"	1 P M.	4 1/16	1 7/8	5 5/8	2 1/8	4 3/4	1 3/4	6 1/16	2 1/8	76	72	9 11/16	4	10 13/16	3 7/8	Cloudy.
"	6 P.M.	4	1 3/4	5 5/8	1 7/8	4 3/4	1 5/8	5 7/8	1 7/8	80	79	9 5/8	3 5/8	10 5/8	3 1/2	Clear.
Aug. 19.	7.30 A M.	4 1/8	1 7/8	5 5/8	2 1/8	4 7/8	1 7/8	6 1/8	2 1/8	73	70	9 3/4	4	11	4	"
"	12 M.	3 7/8	1 15/16	5 3/8	1 7/8	4 11/16	1 3/4	5 13/16	2	84	82	9 1/4	3 13/16	10 5/8	3 3/4	"
"	5.30 P.M.	3 7/8	1 3/4	5 1/8	1 7/8	4 1/2	1 3/4	5 3/8	1 7/8	82	81	9	3 5/8	10 1/8	3 5/8	"
Aug. 20.	7.30 A M.	4 1/16	1 7/8	5 7/16	2 1/2	4 13/16	1 13/16	6 1/8	2 3/16	74	72	9 1/2	4	10 15/16	4	Fair.
"	12 M.	4 1/16	1 13/16	5 1/4	1 3/4	4 9/16	1 3/4	5 11/16	1 15/16	90	84	9 5/16	3 11/16	10 1/4	3 11/16	Clear.
"	5.30 P.M	3 3/4	1 3/4	5 1/8	1 3/4	4 1/4	1 3/4	5 3/4	1 7/8	88	84	8 7/8	3 1/2	10	3 5/8	"
Aug. 21	7.30 A.M.	4 7/8	1 5/8	5 1/2	2 1/8	4 1/8	1 5/8	5 7/8	2 1/8	76	74	10 3/8	3 3/4	10	3 3/4	Cloudy.
Aug. 23.	7.30 A.M.	4	1 3/4	5 3/8	2 1/16	4 3/4	1 3/4	6 1/16	2 1/16	75	72	9 3/8	3 13/16	10 13/16	3 13/16	"
"	6 P.M.	4	1 3/4	5 1/2	2	4 7/8	1 7/8	5 7/8	2	77	77	9 1/2	3 3/4	10 3/4	3 7/8	"
Aug. 24.	7.30 A.M.	4	1 3/4	5 3/8	2 1/16	4 7/8	1 7/8	5 7/8	2 1/16	78	76	9 3/8	3 13/16	10 3/4	3 15/16	Fair.
Aug. 25.	8 A.M.	3 7/8	1 5/8	5 1/2	2	3 7/8	1 3/4	6	2 1/16	80	78	9 3/8	3 5/8	9 7/8	3 13/16	Clear.
"	12 M.	3 3/4	1 5/8	5 1/4	1 3/4	4 1/2	1 5/8	5 3/4	1 7/8	91	90	9	3 3/8	10 1/4	3 1/2	"
Aug. 26.	8 A.M.	3 7/8	1 5/8	5 1/8	1 3/4	4 3/8	1 5/8	6	2 1/8	82	78	9	3 3/8	10 3/8	3 3/4	Fair.
"	5.30 P.M.	3 5/8	1 5/8	5 1/16	1 3/4	4 1/4	1 1/2	5 7/8	1 3/4	92	90	8 11/16	3 3/8	10 1/8	3 1/4	Cloudy.
Aug. 27.	7.30 A.M.	3 7/8	1 9/16	5 1/2	2 1/4	4 9/16	1 1/2	6 1/16	2 1/8	82	78	9 3/8	3 13/16	10 3/8	3 3/8	Clear.
"	12 M.	3 7/8	1 5/8	5 1/8	1 3/4	4 1/2	1 5/8	5 7/8	1 7/8	99	92	9	3 3/8	10 3/8	3 1/2	"
Aug. 28	7.30 A.M.	3 7/8	1 5/8	5 1/4	1 7/8	4 3/8	1 5/8	6	2 1/16	82	80	9 1/8	3 1/2	10 3/8	3 11/16	"
"	12 M	3 7/8	1 9/16	5 1/4	1 7/8	4 3/8	1 3/4	6	2	86	81	9 1/8	3 7/16	10 3/8	3 3/4	Cloudy.
"	5.30 P.M.	3 5/8	1 7/16	5 1/4	1 3/4	4 1/4	1 5/8	5 7/8	1 7/8	80	80	8 7/8	3 3/16	10 1/8	3 1/2	"
Aug. 30.	8 A.M	4 1/8	1 3/4	5 1/4	1 7/8	4 3/8	1 3/4	6 1/16	2 1/16	79	73	9 3/8	3 5/8	10 11/16	3 13/16	Rain.
"	12 M.	3 7/8	1 5/8	5 9/16	2	4 3/8	1 5/8	6	2	78	74	9 7/16	3 5/8	10 3/8	3 5/8	Cloudy.
"	5 P.M.	3 7/8	1 5/8	5 3/8	2	4 3/8	1 5/8	6	2	80	80	9 1/4	3 1/4	10 3/4	3 3/4	Fair.
Aug. 31.	7.30 A.M.	4 1/8	1 3/4	5 5/8	2 1/8	4 7/8	1 3/4	6 3/16	2 1/8	70	66	9 3/4	3 7/8	11 1/16	3 7/8	Clear.
"	12 M.	4	1 3/4	5 5/8	1 7/8	4 3/4	1 5/8	5 7/8	1 7/8	79	76	9 5/8	3 5/8	10 5/8	3 1/2	"
"	5 P.M.	3 7/8	1 3/4	5 3/4	1 7/8	4 7/8	1 3/4	5 7/8	1 3/4	78	77	9 5/8	3 5/8	10 3/4	3 1/2	"
Sept. 1.	7.30 A.M.	4 1/4	1 7/8	5 7/8	2 1/4	5 1/16	1 7/8	6 1/4	2 1/4	64	61	10 1/8	4 1/8	11 5/16	4 1/8	"
"	12 M.	4 1/8	1 7/8	5 3/4	2 1/16	4 7/8	1 7/8	6 1/16	2 1/8	78	75	9 7/8	3 15/16	10 15/16	4	Cloudy.
"	5.30 P.M.	4 1/16	1 7/8	5 3/4	1 7/8	4 3/4	1 3/4	6	1 7/8	76	74	9 13/16	3 3/4	10 3/4	3 5/8	Clear.
Sept. 2.	7.30 A.M.	4 1/4	1 7/8	5 7/8	2 1/4	5	1 7/8	6 1/4	2 1/4	64	62	10 1/8	4 1/8	11 1/4	4 1/8	"
"	12 M.	4	1 3/4	5 3/4	2 1/8	4 7/8	1 3/4	6	2 1/8	72	70	9 3/4	3 7/8	10 7/8	3 7/8	"
Sept. 3.	7.30 A.M.	4 1/8	1 7/8	5 7/8	2 3/16	4 7/8	1 7/8	6 1/8	2 3/16	74	70	10	4 1/16	11	4 1/16	"
"	12 M.	4	1 13/16	5 5/8	1 3/4	4 11/16	1 3/4	5 3/4	1 7/8	88	80	9 5/8	3 9/16	10 7/16	3 5/8	"
Sept. 4.	8 A.M.	4 1/16	1 3/4	5 1/4	2 1/8	4 7/8	1 3/4	6 1/16	2 1/8	79	72	9 5/16	3 7/8	10 15/16	3 7/8	"
"	12 M.	4	1 5/8	5 1/2	2	4 1/2	1 1/2	6	2	90	94	9 1/2	3 5/8	10 1/2	3 1/2	"
"	5.30 P.M.	3 3/4	1 11/16	4 7/8	1 3/4	4 3/8	1 9/16	5 5/8	1 7/8	88	87	8 5/8	3 7/16	10	3 7/16	"
Sept. 14.	7.30 A.M	4 9/16	1 15/16	6 3/16	2 3/16	5 5/8	2	6 5/8	2 3/8	65	59	10 3/4	4 5/8	11 1/4	4 5/8	Fair.

Stress Sheet Tables to Accompany Stress Diagrams Plate XVIII. --Material, Steel.

160-foot Cantilever.

Member.	Mark.	Required. section.	Material used.
		Sq. Inches	
Top chord...............	U_0 U_2	68.3	2 bars 7 × 1 7/16. 2 " 7 × 1 9/16. 2 " 7 × 1 7/8.
"	U_2 U_4	51.0	2 " 6 × 2. 2 " 6 × 2 1/4.
"	U_4 U_6	30.0	4 " 6 × 1 1/4.
"	U_6 U_7	17.25	2 " 6 × 1 7/16.
	U_7 U_8	11.8	2 " 5 × 1 3/16.
Bottom chord...........	L_0 L_2	76.0	2 20 × 3/4. 2 20 × 11/16. 4 L's 4 × 4 × 49 lbs.
"	L_2 L_4	57.0	2 20 × 9/16. 2 20 × 3/8. 4 L's 4 × 4 × 49 lbs.
"	L_4 L_6	33.2	2 20 × 1/2. 4 L's 4 × 4 × 33 lbs.
"	L_6 L_7	20.0	2 20 × 5/16. 4 L's 3 × 3 × 21 lbs.
"	L_7 L_8	....	2 12 × 5/16. 4 L's 2 1/2 × 2 1/2 × 5/16.
Web	U_0 M_1	21.1	2 bars 7 × 1 1/2.
"	M_1 L_2	20.0	2 " 7 × 1 7/16.
"	U_2 M_3	19.0	2 " 6 × 1 3/8.
"	M_3 L_4	17.6	2 " 6 × 1 1/2.
"	U_4 M_5	20.06	2 " 6 × 1 11/16.
"	M_5 L_6	18.07	2 " 6 × 1 1/2.
"	U_6 L_7	12.08	2 " 5 × 1 3/16.
"	U_7 L_7	10.1	2 " 4 1/2 × 1 1/8.
"	U_8 L_8	18.8	4 " 4 1/2 × 1 1/16.
	L_0 M_1	21.3	2 15 × 7/16. 4 L's 3 × 3 × 21.5 lbs.
	M_1 U_2	15.2	4 15 × 5/16. 4 L's 3 × 3 × 18 lbs.
"	L_2 M_3	20.0	2 15 × 3/8. 4 L's 3 × 3 × 21.5 lbs.
"	M_3 U_4	15.14	2 15 × 5/16. 4 L's 3 × 3 × 5/16.
"	L_4 M_5	15.7	2 14 × 5/16. 4 L's 2 1/2 × 2 1/2 × 17.5 lbs.
"	M_5 U_6	11.23	2 14 × 5/16. 4 L's 2 1/2 × 2 1/2 × 5/16.
"	L_6 U_7	12.1	2 12 × 5/16. 4 L's 2 1/2 × 2 1/2 × 15 lbs.
"	L_7 U_8	27.2	2 15 × 1/2. 4 L's 3 × 3 × 30.5.
Suspenders	L_1 M_1	6.2	2 bars 3 1/2 × 7/8.
"	L_3 M_3	6.2	"
"	L_5 M_5	6.2	"

360-FOOT SPAN.

Member.	Mark.	Required section.	Material used.
Top chord	U_0 U_2	71.93	1 24 × ⅜. 2 18 × ⅜. 2 L's 3 × 3 × ⅜. 2 L's 4 × 4 × ½. 2 bars 7 × 1½. 2 " 7 × 1 7/16.
"	U_2 U_4	66.1	Same plates and angles. 2 bars 6 × 1½. 2 " 6 × 1 7/16.
"	U_4 U_6	63.32	1 24 × ½. 2 18 × ⅜. 2 L's 3 × 3 × ⅜. 2 L's 4 × 4 × 41 lbs.
"	U_6 U_8	62.72	2 bars 6 × 1⅞. 1 24 × ⅝. 2 18 × 1. 2 L's 3 × 3 × ⅜. 2 L's 4 × 4 × 37.6 lbs.
"	U_8 U_8	62.4	1 24 × ⅝. 2 18 × 1. 2 L's 3 × 3 × ⅜.
Bottom chord............	L_0 L_2	80.3	2 L's 4 × 4 × 36 lbs. 4 20 × ¾. 4 L's 4 × 4 × 50.7 lbs.
"	L_2 L_4	73.3	2 20 × ¾. 2 20 × ⅝.
"	L_4 L_6	68.1	4 L's 4 × 4 × 45.8 lbs. 4 20 × ⅝.
"	L_6 L_8	66.89	4 L's 4 × 4 × 45.2 lbs. 4 20 × ⅝.
"	L_8 L_9	66.64	4 L's 4 × 4 × 42 lbs. 4 20 × ⅝. L's 4 × 4 × 42 lbs.
Web	U_0 M_1	27	4 bars 6 × 1⅛.
"	M_1 L_2	25.6	2 " 5 × 1¼. 2 " 5 × 1 5/16.
"	U_2 M_3	22.3	4 " 5 × 1⅛.
"	M_3 L_4	21	4 " 5 × 1 1/16.
"	U_4 M_5	17.64	2 12 × 7/16. 4 L's 3 × 3 × 26.5 lbs.
"	M_5 L_6	17.0	2 12 × 7/16. 4 L's 3 × 3 × 22.5 lbs.
"	U_6 M_7	14.45	2 12 × ⅜. 4 L's 2½ × 2½ × 17 lbs.
"	M_7 L_8	14	2 12 × 5/16. 4 L's 2½ × 2½ × 17 lbs.
"	U_8 M_9	14.7	2 12 × ⅜. 4 L's 2½ × 2½ × 5/16.
"	L_0 M_1	33.7	2 16 × ⅝. 4 L's 4 × 4 × 34.2 lbs.
"	M_1 U_2	28.86	2 16 × ½. 4 L's 4 × 4 × 32 lbs.
"	L_2 M_3	27.3	2 15 × 9/16. 4 L's 3 × 3 × 26 lbs.
"	M_3 U_4	23.1	2 15 × 7/16. 4 L's 3 × 3 × 25 lbs.
"	L_4 M_5	21.7	2 15 × 7/16. 4 L's 3 × 3 × 21.5 lbs.
"	M_5 U_6	16.7	2 15 × 5/16. 4 L's 3 × 3 × 18.3 lbs.
"	L_6 M_7	15.1	2 14 × 5/16. 4 L's 3 × 3 × 5/16.
"	M_7 U_8	15.8	2 14 × 5/16. 4 L's 3 × 3 × 5/16.
"	L_8 M_9	14.1	2 12 × 5/16.
Suspenders	L_1 M_1	6.2	4 L's 2½ × 2½ × 16.5 lbs. 2 bars 3½ × ⅞.
"	L_2 M_2	6.2	"
"	Etc.		"

260-FOOT CANTILEVER.

Member.	Mark.	Required section.	Material used.
		Sq. inches	
Pier post	L_0 U_0	77.4	2 36 × $\frac{11}{16}$. 4 L's 4 × 6 × 70 lbs.
Top chord	U_0 U_2	74.0	2 bars 7 × $1\frac{1}{2}$. 2 " 7 × 2. 2 " 7 × $1\frac{23}{32}$.
"	U_2 U_4	68.4	2 " 7 × $1\frac{5}{8}$. 2 " 7 × $1\frac{9}{16}$. 2 " 7 × $1\frac{11}{16}$.
"	U_4 U_6	64.1	1 24 × $\frac{11}{16}$. 2 16 × 1. 2 L's 3 × 3 × $\frac{1}{2}$. 2 L's 4 × 4 × $\frac{11}{16}$.
"	U_6 U_8	61.7	1 24 × $\frac{3}{4}$. 2 16 × $\frac{7}{8}$. 2 L's 3 × 3 × $\frac{1}{2}$. 2 L's 4 × 4 × 51 lbs.
"	U_8 U_9	70.0	1 24 × $\frac{25}{32}$. 2 16 × $\frac{5}{8}$. 2 16 × $\frac{9}{16}$. 2 L's 3 × 3 × $\frac{1}{2}$. 2 L's 4 × 4 × 38.5 lbs.
"	U_9 U_{10}	59.2	1 24 × $\frac{3}{4}$ 2 16 × $\frac{7}{8}$. 2 L's 3 × 3 × $\frac{1}{2}$. 2 L's 4 × 4 × 38.5 lbs.
"	U_{10} U_{11}	48.75	1 24 × $\frac{3}{4}$. 2 16 × $\frac{5}{8}$. 2 L's 3 × 3 × $\frac{3}{8}$. 2 L's 4 × 4 × $\frac{7}{16}$.
"	U_{11} U_{12}	35.1	1 24 × $\frac{7}{16}$. 2 16 × $\frac{7}{16}$. 2 L's 3 × 3 × $\frac{3}{8}$. 2 L's 4 × 4 × $\frac{7}{16}$.
Bottom chord	L_0 L_2	81.3	6 20 × $\frac{1}{2}$. 4 L's 4 × 4 × 53.3 lbs.
"	L_2 L_4	75.3	4 20 × $\frac{11}{16}$. 4 L's 4 × 4 × 50.8. 4 20 × $\frac{5}{8}$.
"	L_4 L_6	67.9	4 L's 4 × 4 × 44.8 lbs.
"	L_6 L_8	63.9	2 20 × $\frac{9}{16}$. 2 20 × $\frac{1}{2}$ 4 L's 4 × 4 × 53.5 lbs.
"	L_8 L_9	66.0	4 20 × $\frac{9}{16}$. 4 L's 4 × 4 × 53 lbs.
"	L_9 L_{10}	53.8	2 20 × $\frac{13}{16}$ 4 L's 4 × 4 × 53 lbs.
"	L_{10} L_{11}	44.0	2 20 × $\frac{3}{4}$. 4 L's 4 × 4 × 35 lbs.
"	L_{11} L_{12}	30.3	2 20 × $\frac{13}{32}$. 4 L's 4 × 4 × 35 lbs.
"	L_{12} L_{13}	23.8	2 20 × $\frac{3}{8}$. 4 L's $3\frac{1}{2}$ × $3\frac{1}{2}$ × 22 lbs.
Web	U_0 M_1	20.47	2 bars 7 × $1\frac{15}{32}$.
"	M_1 L_2	18.85	2 " 7 × $1\frac{11}{32}$.
"	U_2 M_3	18.02	2 " 6 × $1\frac{1}{2}$.
"	M_3 L_4	16.63	2 " 6 × $1\frac{3}{8}$.
"	U_4 M_5	15.0	2 " 5 × $1\frac{1}{2}$.
"	M_5 L_6	14.0	2 " 5 × $1\frac{13}{32}$.
"	U_6 M_7	11.9	2 " 5 × $1\frac{3}{16}$.
"	M_7 L_8	11.3	2 " 5 × $1\frac{1}{8}$.
"	U_8 L_9	8.55	2 " 4 × $1\frac{1}{16}$.
"	U_9 L_{10}	8.93	2 10 × $\frac{5}{16}$. 4 L's $2\frac{1}{2}$ × $2\frac{1}{2}$ × $\frac{5}{16}$.
"	U_{10} L_{11}	10.64	2 10 × $\frac{5}{16}$. 4 L's $2\frac{1}{2}$ × $2\frac{1}{2}$ × $\frac{5}{16}$.
"	U_{11} L_{12}	15.54	2 13 × $\frac{5}{16}$. 4 L's 3 × 3 × 18.5 lbs.
"	U_{12} L_{12}	12.33	2 11 × $\frac{5}{16}$. 4 L's $2\frac{1}{2}$ × $2\frac{1}{2}$ × $\frac{5}{16}$.
End post	U_{12} L_{13}	39.1	1 21 × $\frac{5}{8}$. 2 16 × $\frac{7}{16}$. 2 L's 3 × 3 × $\frac{7}{16}$. 2 L's 4 × 4 × 35.4 lbs.

260-FOOT CANTILEVER—(*Continued.*)

Member.	Mark.	Required section.	Material used.
		Sq. inches.	
Web	L_0 M_1	22.0	2 15 × $\frac{3}{8}$. 4 L's 3 × 3 × 27 lbs.
“	M_1 U_2	16.8	2 15 × $\frac{3}{8}$. 4 L's 3 × 3 × $\frac{5}{16}$.
“	L_2 M_3	18.1	2 13 × $\frac{3}{8}$. 4 L's 3 × 3 × 22.8 lbs.
“	M_3 U_4	14.8	2 13 × $\frac{5}{16}$. 4 L's 3 × 3 × 18 lbs.
“	L_4 M_5	15.7	2 12 × $\frac{5}{16}$. 4 L's 2½ × 2½ × 20.5 lbs.
“	M_5 U_6	12.4	2 12 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
“	L_6 M_7	11.0	2 11 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
“	M_7 U_8	10.1	2 11 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
“	L_8 U_9	8.6	2 10 × $\frac{5}{16}$. 4 2½ × 2½ × $\frac{5}{16}$.
“	L_9 U_{10}	9.7	2 10 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
“	L_{10} U_{11}	11.0	2 10 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
“	L_{11} U_{12}	12.8	2 11 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
Anchor rods	....	....	4 bars 2-inch square iron.

365-FOOT DRAW SPAN.

Top chord	U_0 U_0	26.86	2 bars 5 × 1$\frac{3}{8}$. 2 “ 5 × 1$\frac{5}{16}$.
“	U_0 U_2	25.08	4 “ 5 × 1$\frac{1}{4}$.
“	U_2 U_4	22.1	2 14 × $\frac{7}{16}$. 4 L's 3 × 3 × 25.3 lbs.
“	U_4 U_5	25.83	2 14 × $\frac{1}{2}$. 4 L's 3 × 3 × 30 lbs.
“	U_5 U_6	26.03	2 14 × $\frac{1}{2}$. 4 L's 3 × 3 × 30 lbs.
“	U_6 U_7	21.98	2 14 × $\frac{3}{8}$.
“	U_7 U_8	20.07	4 L's 3 × 3 × 25 lbs.
Bottom chord	L_0 L_0	30.0	2 14 × $\frac{1}{2}$
“	L_0 L_2	29.1	4 L's 3½ × 3½ × $\frac{5}{8}$. 2 14 × $\frac{3}{8}$.
“	L_2 L_4	22.4	4 L's 3 × 3 × 29.8 lbs.
“	L_4 L_5	23.78	2 14 × $\frac{3}{8}$. 4 L's 3 × 3 × 32.2 lbs.
“	L_5 L_6	21.68	2 14 × $\frac{3}{8}$.
“	L_6 L_7	21.15	4 L's 3 × 3 × 28 lbs.
“	L_7 L_8	14.26	2 14 × $\frac{3}{8}$.
“	L_8 L_9	12.91	4 L's 3 × 3 × $\frac{5}{16}$.
Web	U_0 L_0	37.4	2 18 × $\frac{1}{2}$. 4 L's 4 × 4 × 48.5 lbs. iron.
“	U_0 M_1	15.67	2 bars 5 × 1$\frac{1}{16}$
“	M_1 L_2	14.85	2 “ 4 × 1.
“	U_2 M_3	13.70	2 “ 5 × 1$\frac{3}{8}$.
“	M_3 L_4	11.67	2 “ 5 × 1$\frac{3}{16}$.
“	U_4 L_5	7.88	2 “ 4 × 1
End post	U_8 L_9	26.2	2 14 × $\frac{1}{4}$. 4 L's 3 × 3 × 30.5.
Suspender	U_8 L_8	6.12	2 bars 4 × 1. 2 12 × $\frac{3}{8}$.
Web	L_0 M_1	16.0	4 L's 2½ × 2½ × 17.7.
“	M_1 U_2	12.32	2 12 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
“	L_2 M_3	13.47	2 11 × $\frac{5}{16}$ 4 L's 2½ × 2½ × 16.6 lbs.
“	M_3 U_4	11.85	2 11 × $\frac{5}{16}$. 4 L's 2½ × 2½ × $\frac{5}{16}$.
Suspender	L_1 M_1	6.12	2 bars 4 × 1.
“	L_3 M_3	6.12	2 “ 4 × 1.

240-FOOT SPAN.

Member.	Mark.	Required section.	Material used.
		Sq. inches.	
Top chord..............	U_2 U_4	32.5	1 22 × $\frac{3}{8}$. 2 15 × $\frac{3}{8}$. 4 L's 4 × 4 × 33 lbs.
"	U_4 U_6	40.0	1 22 × $\frac{1}{2}$. 2 15 × $\frac{9}{16}$. 4 L's 4 × 4 × 30.4 lbs.
Bottom chord............	L_0 L_2	22.54	4 bars 5 × $1\frac{1}{8}$.
"	L_2 L_4	25.9	4 " 5 × $1\frac{5}{16}$.
"	L_4 L_6	34.0	4 " 5 × $1\frac{3}{16}$. 2 " 5 × 1.
End Post.................	L_0 M_1	37.7	1 22 × $\frac{3}{8}$. 2 15 × $\frac{9}{16}$. 2 L's 4 × 4 × 28.6 lbs. 2 L s 4 × 4 × 34.2 lbs.
"	M_1 U_2	34.2	1 22 × $\frac{3}{8}$. 2 15 × $\frac{7}{16}$. 4 L's 4 × 4 × 32 lbs.
Web	U_2 M_3	11.7	2 bars 5 × $1\frac{3}{16}$.
"	M_3 L_4	10.0	2 " 5 × 1.
"	L_1 M_1	6.06	2 " $3\frac{1}{2}$ × $\frac{7}{8}$.
"	L_2 M_2	6.06	2 " $3\frac{1}{2}$ × $\frac{7}{8}$.
"	L_3 M_3	6.06	2 " $3\frac{1}{2}$ × $\frac{7}{8}$.

160-FOOT SUSPENDED SPAN.

Top chord	U_8 U_9	....	2 14 × $\frac{5}{16}$. 4 L's $2\frac{1}{2}$ × $2\frac{1}{2}$ × $\frac{5}{16}$.
"	U_9 U_{10}	....	2 14 × $\frac{3}{8}$. 4 L's 3 × 3 × $\frac{3}{8}$.
"	U_{10} U_{11}	....	1 20 × $\frac{5}{16}$. 2 14 × $\frac{3}{8}$. 4 L's 3 × 3 × $\frac{3}{8}$.
"	U_{11} U_{12}	....	1 20 × $\frac{7}{16}$. 2 14 × $\frac{3}{8}$. 4 L's 3 × 3 × $\frac{3}{8}$.
Bottom chord...........	L_8 L_9	....	2 12 × $\frac{5}{16}$. 4 L's 3 × 3 × $\frac{3}{8}$.
"	L_9 L_{10}	....	2 12 × $\frac{5}{16}$. 4 L's 3 × 3 × $\frac{3}{8}$.
"	L_{10} L_{11}	....	2 12 × $\frac{7}{16}$. 4 L's 3 × 3 × $\frac{9}{16}$.
"	L_{11} L_{12}	....	4 bars 5 × $1\frac{1}{8}$. 1 18 × $\frac{3}{8}$.
Web	L_8 U_9	....	2 14 × $\frac{3}{8}$. 4 L's 3 × 3 × 19 lbs.
	L_9 U_9	....	2 bars 4 × $1\frac{1}{8}$.
	L_{10} U_9	....	2 " 4 × $1\frac{1}{16}$.
	L_{11} U_{10}	....	2 " 3 × 1.

SUMMARY OF ACTUAL COST OF COMPLETED BRIDGE.

Pier No. 1, cylinder pier		$11 040.27
" 9, "		19 221.57
Piers No. 2 to 8, inclusive, masonry piers—		
Estimates paid—stone	$79 349.54	
" freight on stone	24 602.68	
" laying masonry	85 253.21	
" and Bridge Company's pay-rolls, foundations	53 385.62	
	$242 591.05	
Bridge Company's labor and general expense, net	22 846.98	
		265 438.03
Total substructure		$295 699.87
" superstructure, net		577 200.00
" cost (engineering not included)		$872 899.87

Total number cubic yards masonry = 16 240.

Total cost of masonry per cubic yard in place, $11.67.

Shipping weights of superstructure metal as follows, viz.:

	Iron, pounds.	Steel, pounds.
Two cantilevers 260 feet	508 760	898 756
Two cantilever spans 480 and 483 feet	782 822	1 123 222
One supporting span 360 feet	337 783	884 214
Total cantilever system 1 843 feet	1 629 365	2 906 192
One draw span above table	354 074	211 663
Turn-table	176 625	855
One span 238 feet	256 826	183 746
Cylinder pier bracing and miscellaneous	27 880	72 248
Total, not including engine and cast-iron ornaments	2 444 770	3 374 704

The engineering organization from beginning to the completion of structure was as follows:

President........................ BENNETT H. YOUNG.
Chief Engineer .... JOHN MACLEOD.

Resident Engineers.

PRELIMINARY SURVEYS AND LOCATION.—MACE MOULTON, April 10th, 1881, to June 2d, 1881.

SUBSTRUCTURE.—MACE MOULTON, October 10th, 1881, to May 15th, 1882. Work suspended.

H. P. MCDONALD........ October 1st, 1883, to February 1st, 1884.
C. A. BRADY............ July 1st, 1884, to June 6th, 1885.

Assistant Engineer.

J. K. ZOLLINGER............ October 10th, 1881, to June 6th, 1885.

SUPERSTRUCTURE.

Chief Assistant Engineer.—MACE MOULTON, February 16th, 1885, to July 15th, 1886.

Assistant Engineer on Calculations.—J. W. SCHAUB.

Inspecting Engineers.

MATERIAL.—H. GOLDMARK, Cambria Iron Company and Pennsylvania Steel Company.
" G. W. G. FERRIS, Carnegie Brothers & Co.

WORKMANSHIP AND MATERIAL.—W. H. BREITHAUPT, Athens Shop.
" " W. R. WEBSTER, New Jersey Steel and Iron Company's Shop.

Bridge completed July 15th, 1886.

The following illustrations are given herewith.

Plate XIII. The structure completed.
" XIV. Map showing location of bridge.
" XV. Rise and fall of Ohio River at bridge site.
" XVI. Original design by C. Shaler Smith, and final design by Charles Macdonald and Edward Hemberle.
" XVII. Erection devices for joining cantilevers.
" XVIII. Stress diagrams.
" XIX. Cross section of floor.
" XX. Posts made from tension and compression steel.
" XXI. The structure in progress.

APPENDIX.

EXTRACTS FROM SPECIFICATIONS.

General Description.

The total length of bridge will be 2 453 feet center to center of abutment.

The length of the different spans is given below, commencing at the Kentucky shore. Center to center of piers.

Shore span	260 feet.
Span over canal	483 "
" Sand Island	360 "
" main river	480 "
" "	260 "
Draw span, total length	370 "
Indiana shore span	240 "
Total length	2 453 feet.

The structure will be built for a single track railroad, two (2) roadways not less than ten (10) feet wide in the clear, and two (2) sidewalks each four (4) feet in width in the clear.

The railroad track to be placed in the center between the two trusses; one roadway on the outside of each truss, supported upon projecting brackets; and the sidewalks one on either side of the railroad track and inside the main trusses.

The clear width between trusses shall not be less than twenty-two (22) feet.

There will be substantial wooden hand-rails on the outer line of the roadways, and between the sidewalks and the railroad track, and close wooden partitions eight (8) feet high between the sidewalks and the roadways.

The entire superstructure will be of wrought-iron and steel, with the exception of the roadway and sidewalk floors, and the ties and guard-rails for the railroad, which will be of timber, as below indicated. Steel will be used for top and bottom chords, end braces, pins, bearing plates and rollers. Longitudinal stringers to be of Southern pine, 7 by 16 inches, spaced about two feet apart.

Lower floor of roadway to be 3-inch oak.

Upper floor of roadway to be 2-inch spruce.

Floor of sidewalks to be 2-inch Southern pine.

Ties to be white oak.

Guard-rails to be yellow pine.

Cast-iron may be used for the construction of the center circular track, wheels, etc., of the turn-table of the draw.

Proportion of Parts and Details of Construction.

The bridge will be proportioned to carry, in addition to its own weight, the following moving loads, viz.:

For railroad traffic, a train of freight cars weighing 2 240 pounds per foot and drawn by two (2) standard consolidation locomotives weighing 57 tons each; and for the roadway and sidewalk traffic, 1 200 pounds per lineal foot of bridge.

	Engine.					Tender.				Train.
Load, pounds....	16 000	24 000	24 000	24 000	24 000	16 000	16 000	16 000	16 000	2 240 pounds per foot.
Feet.......	7' 6''	4' 6''	4' 6''	4' 6''	10' 6''	5' 0''	5' 6''	5' 0''	8' 0''	

	Engine.					Tender.				Train.
Load, pounds....	16 000	24 000	24 000	24 000	24 000	16 000	16 000	16 000	16 000	2 240 pounds per foot.
Feet.......	7' 6''	4' 6''	4' 6''	4' 6''	10' 6''	5' 0''	5' 6''	5' 0''	3' 0''	

This moving load of engines and train of loaded cars being distributed as show in the foregoing diagram, and considered in positions and conditions giving the greatest results.

To provide for the effect of impact, all such parts of the structure as are liable to be subjected to sudden strains or vibrations shall be calculated with additions to the above specified rolling load as follows:

	Per cent.
Floor-beam hangers and riveted connections of stringers and floor beams............................	100
Floor-beam vertical suspenders over 15 feet long	50
Stringers, floor beams and members subjected to counterstrain	25

The maximum and minimum stresses in compression and tension, as found for the before mentioned loads, with a factor of safety of not less than five, are to be used in determining the permissible working stress in each piece of the structure according to Launhardt's formula, as follows:

$$a = u\left(1 + \frac{\text{minimum stress in member}}{2 \text{ maximum stress in member}}\right)$$

In the above formula	Pounds per square inch.
a = permissible stress per square inch for double refined iron in tension (links or rods)	9 000
u = for double refined steel in tension...........	14 000
u = for rolled iron in tension (plates or shapes)..	8 500
u = for rolled steel in tension....................	14 000
u = for rolled iron in compression	7 500
u = for rolled steel in compression	13 000

The permissible stress per square inch for members in compression is to be reduced in proportion to the ratio of the length to the least radius of gyration of the section, by the following formula:

$$\text{For both ends fixed, } b = \frac{a}{1 + \frac{l^2}{40\,000\, r^2}}$$

$$\text{For one end jointed, } b = \frac{a}{1 + \frac{l^2}{30\,000\, r^2}}$$

$$\text{For both ends jointed, } b = \frac{a}{1 + \frac{l^2}{20\,000\, r^2}}$$

When a = permissible stress previously found.
b = the allowable working stress per square inch.
l = length of piece in inches center to center of connections.
r = radius of gyration of the section in inches.

To provide for wind strains and vibration, the bottom lateral bracing shall be proportioned to resist a force at right angles to the axis of the bridge equivalent to 450 pounds per foot of span. For top lateral bracing, 150 pounds per foot of span.

The permissible working strains in the lateral bracing as determined by the above assumption, may be 50 per cent. greater than the values determined by the formula for loads as previously given. But in no case shall any lateral or diagonal rod have a less area than three-fourths of a square inch.

The unsupported width of any plate subjected to compression shall never exceed thirty times its thickness ; nor shall any plate be less than five-sixteenths of an inch thick.

The sections of top chords shall be connected at all abutting joints by splices sufficient to hold them truly in position.

In rolled I beams the compression per square inch in the compression flanges must not exceed

$$\frac{10\,000}{1 + \frac{l^2}{5\,000\, b^2}}$$

In riveted girders, $$\frac{8\,000}{1 + \frac{l^2}{5\,000\,b^2}}$$

Where l = length of unsupported compressed flange in inches, b = breadth in inches of the compressed flange.

The shearing strain per square inch of I beams and girders must not exceed $$\frac{8\,000}{1 + \frac{d^2}{3\,000\,t^2}}$$

Where d = distance between flanges or stiffeners measured on a line inclined 45 degrees, and t = thickness of web in inches.

The shearing strain on wrought-iron pins must not exceed 7 000 pounds per square inch, nor on steel pins 10 000 pounds per square inch.

The strain on extreme fibers caused by bending must not exceed 15 000 pounds per square inch for wrought-iron, nor 20 000 pounds per square inch for steel pins, the forces being considered as applied at center of bearing, each surface. The bearing strain on an area equal to the diameter of the pin multiplied by the thickness of the head must not exceed 12 000 pounds per square inch for wrought-iron, nor 18 000 pounds per square inch for steel pins.

The shearing strain on rivets must not exceed 7 000 pounds per square inch if of wrought-iron, nor 10 000 pounds per square inch if of steel. The bearing strain on the surface of rivets (diameter of rivet multiplied by thickness of plate) must not be more than 10 000 pounds per square inch if of wrought-iron, nor more than 15 000 pounds per square inch if of steel, for all rivets used in bearing and splice plates. For rivets in all other positions a maximum bearing strain of 12 000 pounds per square inch if of wrought-iron, and 18 000 pounds per square inch if of steel, will be allowed. Rivets will not be used where they may be subjected to tensile strain. No allowance will be made for countersunk rivets when countersink is in a plate less than ⅜ of an inch thick.

The heads of eye-bars must not be inferior in strength to the body of the bar. The form of the head and the mode of manufacture shall be subject to the approval of the engineer.

In compression members the distance from center to center of rivets must not exceed six inches, or sixteen times the thickness of any of the joined plates, and the pitch of rivets for a distance of two diameters from the ends shall be four times the diameters of the rivets; but in no case shall the pitch of the rivets be less than four times the diameters of the rivets.

The sectional area of rivets in one segment, in the distance of two diameters from the end, must not be less than the sectional area of the segment.

Where columns composed of two segments latticed are used, the number of rivets in end tie-plates shall be sufficient to transfer one-half of the strain coming on the column across from one segment to the opposite segment independent of the lattice.

All segments must be of one length, without break, whenever practicable. For trough-shaped columns the number of rivets in lower tie-plate shall be sufficient to transfer one-fourth of the strain coming on the column.

Where lattice-work is used, the angle of the lattice bars with center line of the member shall be about forty-five degrees. The size of the bars shall be proportioned to the width of the members and the strain to which they may be subjected.

The distance between the edge of any piece and center of rivet-hole must never be less than one and one-fourth inches, except in bars less than two and one half inches wide; where practicable it shall be at least two diameters of rivets.

When plates more than twelve inches wide are used in the flanges of riveted girders, an extra line of rivets with a pitch of not less than nine inches shall be driven along each edge to draw the plates together and prevent entrance of water.

All joints in riveted girders, whether in tension or compression, must be fully spliced, as no reliance will be placed on abutting joints. The ends however must be dressed straight and true, so as to leave no open joints. The web of plate girders must be spliced at all joints by a plate on each side of the web.

The diameter of rivets will ordinarily be three-fourths or seven-eighths inch.

Floor-beam suspension bars are to be so arranged by means of equalizers, or otherwise, as to secure equal strains on all links supporting the same floor beam.

Rods with screw ends shall be upset at the ends so as to make the diameter at the bottom of the threads one-eighth inch larger than any part of the body of the bar. The nuts must have a true and square bearing on the surface they rest upon, be easily accessible with a wrench for the purpose of adjustment, and be effectively checked after the final adjustment, as also all pin nuts.

There must be a bearing plate or box of approved form under both ends of all spans of sufficient depth to distribute the weight properly on masonry. These plates must be of such dimensions that the greatest pressure upon the masonry will not exceed 200 pounds per square inch.

All deck and through spans, excepting the channel span, must have at one end nests of turned friction rollers of steel running between planed surfaces. The rollers must not have less than three inches diameter, and shall be so proportioned that the pressure in pounds per lineal inch of rollers shall not exceed $\sqrt{540\,000\ d}$ (d being the diameter of the rollers in inches).

All spans must be sufficiently anchored to the masonry to resist displacement by the strongest wind specified.

All connections and details of the several parts of the structure shall be of such strength, that upon testing, rupture shall occur in the body of the members rather than in any details or connections.

All surfaces not in contact with other surfaces must be accessible to inspection, cleaning and painting after erection. No closed work will be allowed in the structure.

MATERIALS.

STEEL.—The steel shall be manufactured by the open-hearth process; Bessemer steel will not be accepted. A sample bar three-quarters of an inch in diameter shall be rolled from every melt; if this bar fails to meet the requirements of the laboratory tests the whole charge shall be rejected.

Steel used in compression members, bolsters, bearing plates, pins and rollers shall contain not less than $\frac{34}{100}$ nor more than $\frac{42}{100}$ of one per cent. of carbon, and less than one-tenth per cent. of phosphorus. A sample test bar three-quarters of an inch in diameter shall bend 180 degrees around its own diameter without sign of crack or flaw. The same bar, tested in a lever machine, shall show an elastic limit of not less than 50 000 pounds and an ultimate strength of not less than 80 000 pounds per square inch; it shall elongate at least 15 per cent. in a length of eight inches before breaking, and shall have a reduced area of 35 per cent. at the point of fracture. It shall be incapable of tempering.

Steel for rivets and eye-bars shall contain not more than $\frac{25}{100}$ of one per cent. of carbon, and less than one-tenth of one per cent. of phosphorus. A sample bar three-quarters of an inch in diameter shall bend 180 degrees and be set back upon itself without showing crack or flaw. When tested in a lever machine it shall have an elastic limit of not less than 40 000 pounds, and an ultimate strength of not less than 70 000 pounds per square inch; it shall elongate at least 18 per cent. in a length of eight inches, and shall show a reduction of at least 42 per cent. at the point of fracture. In full-sized bars this steel shall have an elastic limit of at least 35 000 pounds, and an ultimate strength of at least 65 000 pounds per square inch; it shall elongate at least 10 per cent. before breaking, and for strains less than 30 000 pounds per square inch shall show a modulus of elasticity between 28 000 000 and 30 000 000 pounds.

Facilities for testing the sample bars shall be furnished by the contractor at a point convenient to the steel-works, and tests shall be made at the expense of the contractor, and under the direction of the engineer. All plates for this work of both iron and steel shall be rolled in a universal mill.

Steel for pins shall not be hammered, but rolled between gothic rolls. All rolled beams, channels, bars, angles, plates, etc., must be straight and out of wind. They must be free from flaws, fins, blisters, seams, and cracked edges. Angles and edges must be sharp and well filled out. Flaws, surface imperfections, or irregular shapes will be sufficient ground for the rejection of material

Specifications for iron and timber are as usual in first-class work.

All specifications for workmanship as usual in first-class work; the holes in riveted steel to be punched $\frac{1}{16}$ inch smaller diameter than nominal diameter of rivet and then reamed, with edges of reamed holes filed to take off burr left by drill.

NOTE.—The following changes and supplementary requirements were considered best by the writer, and the work was done in accordance therewith.

Compression steel to be used as specified, except for pins—lower limit of carbon fixed at 0.28 per cent.

Tension steel to be used for eye-bars; also for riveted members subject to tension or alternate stresses; also for pins. This grade was not used for rivets; carbon limits changed to vary between 0.18 and 0.28 per cent.

Rivet steel. Carbon not specified. Ultimate strength to vary between 58 000 and 65 000 pounds per square inch with severe bending and quenching tests.

All rivet holes in steel were reamed except those in lacing bars. All plates were either universal mill or groove-rolled plates. No planing of end of plates was required, except where proper finish required it.

The only case of hammering steel plate allowed was that mentioned in "special tests."

Eye-bars were made by upsetting and head finished under the hammer.

Eye-bar heads proportioned in general with 50 per cent. excess material across eye when pin diameter equaled width of bar, the percentage of excess decreasing as the diameter of pin exceeded the width of bar. Steel lateral bar upsets were made with care, providing against sudden changes in shape and sharp corners. Threads were cut with V threads, with fillet at bottom.

All reaming and drilling was done with rigidly-fixed vertical drills, and parts riveted up without taking apart.

All ends of members where sheared or punched off for clearance requirements were carefully chipped so as to leave no sharp re-entrant angles.

TESTS ON MATERIAL AND FINISHED PARTS.

The various records of tests made on material and finished parts have been placed by themselves in order to separate the descriptive from the special matter and immediately follow in two classes.

1st. *Regular tests* made to determine quality, with view to acceptance or rejection of material.

2d. *Special tests* made for the purpose of determining questions arising during the progress of the work, or with a view to testing the soundness of prevalent theories as applied to the material in hand.

REGULAR TESTS.

As will be seen from specification the quality of the steel was to be determined by the tests on ¾" rounds rolled from ingots. No further provision was made therein for future rejection on score of quality, and with this we were obliged to be satisfied with the finished eyebar and angle bars made at Johnstown. However, by courtesy of the Union Bridge Company, extra lengths of angle bars and extra bars of eyebar steel were ordered and test pieces cut therefrom which enabled us to know how the steel was running. All tests given are on steel accepted, except where otherwise noted.

From the start the mills were notified that all finished material must have the original heat number stamped or stenciled on in order that future reference might be made to them. In material rolled at Carnegie's, however, the tests were made on crop ends of finished plates to determine state of the material as regards overheating in furnaces in which slabs were heated for rolling into finished plate. Very few rejections occurred, but the series of tests gave us satisfactory assurance of the excellence of the finished product.

I have collected all tests made on material from each original heat, both ¾" round from ingots and finished steel, so that it may be judged how much or how little relation there may be existing between the condition of the two. The tests recorded for plate steel, were made at the Union Iron Mills, Pittsburgh, and the ingot tests at the works of the Penna. Steel Co., at Steelton, and were all made with care.

The work done on the test pieces at Steelton was as follows:—14" square ingot heated and rolled to 7" square; 7" square heated and hammered to 4" square; 4" square heated and rolled to 1¾" x 2" square; this heated again and rolled to ¾" round test bar. This bar then tested without machine finish. In all cases where modulus of elasticity is recorded, the elongations by which it was determined were taken by an instrument with an electric contact micrometer reading attachment.

Work done on plate material. Plates ½" thick and under rolled from slabs made 4" thick x ½" wider than finished plate. These slabs either hammered or rolled in universal mill from ingots. Plates over ½" thick same, except that slabs were 5" thick.

Plates over 18" wide made from 20"x20" ingots, and for plates over 20" wide ingots first spread under hammer, and then rolled to required size. Plate test pieces planed from plates—generally 1" wide.

PLATES USED IN *TENSION*, OR ALTERNATE *TENSION* AND *COMPRESSION*, ½ INCH THICK AND UNDER.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
6/11	4528	15×⅜	.4821	47.080	72.910	24.0	53.0	180° round ½″			
"	"	12×7/16	.4250	43.950	73.530	25.0	55.0	"			
5/26	"	12×⅜	.3342	50.000	74.600	22.0	57.7				
"	"	12×7/16	.3913	43.730	73.240	24.0	48.3				
7/29	"	12×⅜	.3805	51.328	75.530	23.8	55.3				
4/20	"	¾ round	......	50.066	74.266	24.3	52.9	From 14″×14″ Ingot	.21	.71	
"	"	"	......	49.040	74.020	25.0	51.9	"	"	"	
"	"	"	......	46.130	71.290	24.1	57.4	"	"	"	Test piece annealed.
5/	"	"	......	55.660	78.700	25.0	53.3	No. 1 20″×20″ Ingot	.25		
"	"	"	......	54.270	78.500	25.0	55.3	" No. 1	"		
"	"	"	......	51.070	74.070	25.0	58.2	" No. 2	.22		
"	"	"	......	51.560	74.700	25.7	55.5	" "	"		
"	"	"	......	53.490	76.070	25.5	58.6	" No. 3	.21		
"	"	"	......	52.570	74.770	26.0	59.0	" "	"		
"	"	"	......	47.320	72.180	25.5	55.5	" No. 4	.22		
"	"	"	......	46.500	72.150	27.2	58.6	" "	"		
"	"	"	......	46.370	73.530	24.0	52.7	" No. 5	.21		
"	"	"	......	46.130	73.750	27.0	58.8	" "	"		
"	"	"	......	47.420	72.130	27.0	55.5	" No. 6	.21		
"	"	"	......	47.960	70.360	26.5	56.5	" "	"		
5/8	4536	12×⅜	.3249	46.170	78.180	21.3	52.7	180° round ½″			
"	"	"	.3478	45.740	80.790	20.6	49.7	" " ⅝″			
6/11	"	12×7/16	.3654	46.090	77.180	21.3	50.8	" " ½″			
6/12	"	18×⅜	.3602	48.530	75.850	18.0	38.7	" " ½″	....	....	Slag pits on surface.
7/17	"	14×5/16	.3187	43.645	75.458	23.0	55.6	178° " ⅝″			
4/20	"	¾ round	......	50.570	75.710	25.3	52.7	14″×14″ Ingot	.23	.89	
"	"	"	......	51.310	76.300	25.0	50.1	"	"	"	
"	"	"	......	47.530	72.420	21.6	56.6	"	"	"	Test piece annealed.
5/	4536	¾ round	......	54.860	78.170	25.1	56.0	No. 1 20″×20″ Ingot			
"	"	"	......	55.670	78.810	24.6	57.6	" No. 1			
"	"	"	......	50.750	76.730	25.2	54.1	" No. 2			
"	"	"	......	50.870	76.860	23.9	54.0	" "			
"	"	"	......	54.100	76.220	26.2	53.4	" No. 3			
"	"	"	......	49.700	77.230	25.0	54.0	" "			
"	"	"	......	48.450	77.280	24.2	56.7	" No. 4			
"	"	"	......	48.780	78.090	25.7	57.3	" "			
"	"	"	......	47.740	74.180	27.0	54.5	" No. 5			
"	"	"	......	47.520	74.490	26.2	54.6	" "			
"	"	"	......	50.600	78.820	23.9	49.4	" No. 6			
"	"	"	......	51.650	79.050	25.0	46.3	" "			
6/11	4586	18×7/16	.4300	46.050	74.120	22.5	53.1	180° round ⅜″			
6/12	"	18×⅜	.3881	49.860	77.940	18.8	45.5	" " ½″			
"	"	"	.3596	49.600	75.530	23.0	47.3				
6/25	"	18×½	.5135	40.700	73.840	24.5	46.9	180° " 7/16″			
7/17	"	12×5/16	.3013	46.304	71.360	23.8	54.6				
5/5	"	¾ round	......	49.300	75.420	24.2	49.5	14″×14″ Ingot	.19	1.01	
"	"	"	......	49.530	76.330	24.1	48.4	" "			
6/11	4587	18×½	.5057	44.570	74.708	21.0	47.1	180° round ⅜″			
"	"	"	.5133	50.000	76.000	21.3	38.6	" " ⅝″	....	....	Plate pu'ch'd very hard
5/14	"	¾ round	......	46.400	72.320	25.2	54.0	14″×14″ Ingot	.21	.86	
"	"	"	......	50.600	76.110	25.0	48.5	" "			
6/11	4590	18×⅜	.3147	47.200	75.850	23.0	51.2	180° round ½″			
6/25	"	18×½	.5100	44.000	74.800	22.0	48.3	182° " ⅝″	..	.. .	Plate pu'ch'd very hard
0/13	"	28×5/16	.2590	49.540	77.030	14.5	55.3				Broke near jaws
5/14	"	¾ round	......	45.790	69.150	26.7	55.5	14″×14″ Ingot	.23	.65	Fracture irregular.
"	"	"	......	46.070	69.030	27.0	55.6	" "	....	....	" "
6/25	4593	12×5/16	.3175	45.170	70.000	24.0	59.2	180° round ⅜″			
5/14	"	¾ round	.....	48.100	71.930	24.1	43.5	14″×14″ Ingot	.18	.70	
"	"	"	......	47.760	71.580	25.1	43.5	" "			

6/25	4649	7×⅜	.3477	44.400	81.100	19.5	36.5	178° round ½″	....	....	Broke in flaw.
7/17	"	14×5/16	.3245	47.763	75.495	22.0	55.5	180° " ⅝″			
6/11	"	¾ round	......	48.030	73.450	25.0	48.8	14″×14″ Ingot	.31	.75	
"	"	"	......	47.840	74.000	25.5	49.9	" "			
7/27	4555	15×7/16	.4382	43.360	71.008	18.0	44.6	175° round ¾″			
5/5	"	¾ round	......	50.140	72.950	24.0	46.5	14″×14″ Ingot	.21	.65	
"	"	"	......	50.750	73.730	27.7	47.1	" "			
7/29	4557	11×⅜	.3514	51.225	75.695	21.3	53.9				
8/11	"	20×⅜	.3673	42.880	72.828	21.3	56.3				
5/5	"	¾ round	......	46.070	70.700	24.3	48.1	14″×14″ Ingot	.20	.66	
"	"	"	......	47.130	71.930	26.7	47.6	" "			
7/17	4561	12×7/16	.4078	46.221	70.978	25.0	55.6	178° round ¾″			
5/5	"	¾ round	......	51.670	74.570	25.9	55.6	14″×14″ Ingot	.22	.65	
"	"	"	......	51.330	74.330	25.0	56.2	" "			
7/27	4643	16×½	.4965	45.316	76.330	23.8	54.3	180° round 1⅛″			
6/20	"	¾ round	......	47.490	73.170	26.0	52.2	14″×14″ Ingot	.31	.87	
"	"	"	......	46.150	73.280	26.0	53.1	" "			
7/27	4646	16×½	.5015	43.423	73.805	22.5	51.5				
6/11	"	¾ round	......	48.010	72.430	27.0	49.0	14″×14″ Ingot	.25	.82	
"	"	"	......	47.010	72.470	26.3	49.9	" "			
6/20	"	"	......	49.220	78.160	26.2	51.2	" "			
"	"	"	......	49.220	78.160	25.0	51.2	" "			
7/29	4662	13×5/16	.3065	45.695	75.370	21.3	46.9				
6/20	"	¾ round	......	46.400	72.520	26.0	53.8	14″×14″ Ingot	.20	.73	
"	"	"	......	46.400	72.320	25.2	54.0	" "			
8/4	4656	24×½	.3911	45.000	75.556	16.3	31.8	....	....	....	Broke near jaws.
8/26	"	24×⅜	.3486	54.415	78.595	15.5	33.2	....	...	....	Several surface flaws.
6/20	"	¾ round	......	51.620	73.890	24.5	41.4	14″×14″ Ingot	.19	.82	Test piece much cold rolled.
"	"	"	......	51.230	73.770	25.0	41.6	" "			
7/27	4645	15×⅜	.3800	47.185	73.685	26.0	57.3				
8/26	"	24×⅜	.3325	52.540	79.400	21.2	55.3				
6/11	"	¾ round	......	47.720	72.170	24.9	46.0	14″×14″ Ingot	.20	.76	
"	"	"	......	47.750	72.680	26.7	48.8	" "			
7/17	4678	7¼×⅜	.3653	45.852	71.990	23.5	52.8				
"	"	13×5/16	.2864	48.010	74.542	22.5	58.6	180° round ¾″			
"	"	"	3110	48.230	73.150	23.0	58.0	181° round ½″			
"	"	12½×⅜	.3650	43.010	71.750	23.3	53.6				
6/20	"	¾ round	.. ..	48.460	73.100	26.2	54.4	....	.20	.86	
"	"	"	.....	47.960	73.520	25.5	54.7				
7/27	4716	15×½	.4925	47.327	75.594	25.0	57.4				
6/3	"	¾ round	......	47.350	70.930	23.8	45.6	14″×14″ Ingot	.24	.86	
"	"	"	......	47.220	70.540	26.5	43.9				
7/27	4720	16×½	.4885	45.035	71.955	23.8	51.8				
7/29	"	11×5/16	.3269	52.613	77.295	23.3	53.0				
6/3	"	¾ round	......	46.140	70.300	24.3	45.1	14″×14″ Ingot	.21	.66	
"	"	"	......	46.200	70.620	25.8	45.9	....	.22	.63	
8/25	4728	16×½	.3871	49.470	73.110	23.8	53.3				
9/8	"	20×7/16	.3336	52.250	83.150	22.5	53.4				
7/22	"	¾ round	....	50.070	78.140	24.9	49.5	14″×14″ Ingot	.26	.75	Cold rolled. E=30.-190.000.
"	"	"	......	48.990	77.010	23.0	44.3	" "			
9/8	4743	16×½	.4000	43.995	69.990	24.3	51.5				
7/31	"	¾ round	.. ...	43.360	69.280	26.3	52.9	....	.21	.65	
"	"	"	......	44.050	69.740	27.3	53.4				
8/25	4738	16×½	.3930	47.250	70.865	26.0	52.2				
"	"	20×5/16	.2434	53.575	82.780	18.8	46.1				
7/30	"	¾ round	......	43.490	68.810	27.3	58.0	....	.19	.74	
"	"	"	......	45.060	68.840	27.3	58.6				
12/9	4866	14×⅜	.3718	43.690	74.280	25.0	55.5	180°-close			
10/22	"	"	.3157	48.305	74.600	23.3	53.0				
9/28	"	¾ round	......	47.360	73.250	26.3	48.1	....	.20		
"	"	"	......	48.020	73.080	24.0	46.5				
12/4	4976	22½×⅜	.3656	51.420	82.400	19.4	56.6	180° round ⅝″			
"	"	"	.3694	50.620	80.230	22.0	54.4	178° " 7/16″			
"	"	25×⅜	.3781	52.100	80.000	20.0	51.2	182° " 7/16″			
11/11	"	¾ round	......	50.770	76.650	22.5	52.0	14″×14″ Ingot			
"	"	"	......	50.070	76.560	25.0	50.4	" "			
11/13	"	"	.. ...	53.960	77.300	22.7	47.0	" "	.25	.77	
10/14	4776	20×7/16	.3684	45.410	76.000	21.0	54.3				
"	"	17¾×⅜	.3881	46.120	75.880	23.0	54.5				
8/8	"	¾ round	......	47.750	75.150	24.3	46.4	....	.22	.76	
"	"	"	......	48.590	74.940	25.0	4[illegible].1				
10/24	4868	13¼×5/16	.2790	47.135	74.440	23.8	50.8				
9/28	"	¾ round	... ..	49.330	74.650	23.8	49.7	... .	.21		
"	"	"	......	49.350	74.720	25.0	51.6				
10/26	4731	13×½	.4553	43.380	71.205	25.6	56.8				
7/22	"	¾ round	......	54.200	73.910	26.4	55.2	....	....	....	E=31.160.000.
"	"	"	......	51.340	71.290	26.8	47.0	....	.21	.68	

PLATES USED IN *TENSION* OR ALTERNATE *TENSION* AND *COMPRESSION*—OVER ½ INCH THICK.

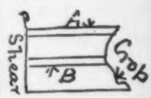
Date, 1885.	Heat No.	Specimen cut from	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
7/1	4519	20×⅝	.4788	43.650	73.520	21.3	46.9				
7/3	"	20×¾	.5625	42.280	71.336	23.8	49.3	180° round 1⅛″			
4/20	"	¾ round	......	49.130	73.950	25.3	49.1	14″×14″ Ingot	.22	.58	
"	"	"	......	49.660	74.000	23.9	49.1	"			
4/21	"	"	......	46.490	70.870	23.3	53.7	"			
7/3	4570	20×¾	.5625	42.507	69.333	22.0	43.9	180° round 1¾″			
"	"	"	.4785	41.190	68.340	20.8	40.8	180° round 1½″			
5/5	"	¾ round	......	46.280	70.530	25.2	49.1	14″×14″ Ingot	.23	.71	
"	"	"	......	46.880	71.130	24.7	49.0	"			
7/1	4557	20×¾	.4125	43.636	78.930	18.3	42.3				
7/3	"	"	.5476	41.510	68.660	20.8	40.8	180° round 1½″	....	....	Broke in scale pits.
5/5	"	¾ round	......	46.070	70.700	24.3	48.1	14″×14″ Ingot	.20	.66	
"	"	"	......	47.130	71.930	23.7	47.6	"			
7/1	4561	20×¾	.4706	44.470	71.630	21.3	48.8	180° round 1¼″	....	....	Showed blow holes.
"	"	"	.4703	43.590	71.870	22.5	41.8				
5/5	"	¾ round	......	51.670	74.570	25.9	55.6	14″×14″ Ingot	.22	.65	
"	"	"	......	51.330	74 330	25.0	56.2	"			
8/3	4588	20×⅝	.5293	44.455	72.170	23.8	46.5				
5/14	"	¾ round	......	50.250	76.350	25.3	43.6	14″×14″ Ingot	.27	.78	
"	"	"	......	50.420	76.510	24.0	41.8	"			
7/1	4590	20×¾	.4556	43.920	76.240	25.0	47.9				
5/14	"	¾ round	......	45.790	69.150	26.7	55.5	14″×14″ Ingot	.23	.65	
"	"	"	......	46.070	69.030	27.0	55.6	"			
6/11	4587	18×⅝	.5990	41.240	70.950	24.5	45.7	180° round ¾″			
"	"	18×⁹⁄₁₆	.4950	43.780	72.464	23.4	48.9	180° round ⅝″	....	....	Punched hard in spots.
"	"	"	.4873	41.040	75.100	22.0	46.8	"	....	....	"
5/14	"	¾ round	......	46.400	72.320	25.2	54.0	14″×14″ Ingot	.21	.86	
"	"	"	......	50.600	76.110	25.0	48.5	"			
6/11	4586	18×⅝	.6047	43.000	73.750	22.0	44.0	180° round ⁹⁄₁₆″			
5/5	"	¾ round	......	49.300	75.420	24.2	49.5	14″×14″ Ingot	.19	1.01	
"	"	"	......	49.530	76.330	24.1	48.4	"			
8/4	4721	20×⅝	.4406	43.258	66.275	23.8	48.8	....	....	...	Broke in surface flaw.
"	"	"	.5562	42.251	66.253	23.3	50.9	....	....	....	" bad "
7/29	"	"	.6076	47.235	70.470	26.3	47.9				
"	"	"	.6139	46.733	73.500	20.0	45.8				
7/3	"	¾ round	......	46.920	70.260	25.7	43.3	14″×14″ Ingot	.20	.72	
"	"	"	......	45.780	70.370	23.0	42.3	"			
8/17	4720	20×⅝	.6075	41.810	74.760	21.0	49.1	....	....	...	When punched showed soft spots.
8/4	"	"	.4431	46.942	73.460	22.0	52.3	....	....	...	
6/3	"	¾ round	......	46.140	70.300	24.3	45.1	14″×14″ Ingot	.22	.63	
"	"	"	......	46.200	70.620	25.8	45.9	"			
7/27	4682	15×⁹⁄₁₆	.5609	44.213	72.028	20.3	49.9				
8/3	"	20×¾	.6497	40.957	74.465	22.5	41.6				
6/29	"	¾ round	......	48.540	73.500	[illegible]	52.9	14″×14″ Ingot	.20	.81	
"	"	"	......	48.910	74.230	26.2	52.7	"			
[illegible]/29	4718	13×⁹⁄₁₆	.5483	43.459	68.482	25.8	52.4				
"	"	"	.5351	43.600	70.730	23.3	50.6				
"	"	16×⅝	.5177	44.654	71.130	29.0	54.4				
8/26	"	20×1⅝	.5026	37.800	69.250	24.5	51.9	....	....	....	Specimen round.
6/3	"	¾ round	......	46.960	70.260	23.6	42.4	14″×14″ Ingot	.23	.65	
"	"	"	......	47.210	70.430	24.3	41.3	"			
8/25	4732	24×¾	.4858	44.555	71.180	17.5	44.9	....	....	....	Bad surface flaw.
12/9	"	9×¾	.6309	43.690	71.280	23.3	46.0	180° round ¼″			
"	"	7×1⅛	.5281	40.950	71.620	27.0	53.4	180° round ⅛″	....	....	Specimen round.
7/22	"	¾ round	......	47.580	70.140	22.1	49.8	14″×14″ Ingot	.21	.72	E=29.700.000.
"	"	"	......	46.920	69.030	23.3	47.2	"			
8/11	4733	20×¾	.5437	49.767	71.180	25.0	48.5				
7/22	"	¾ round	......	54.570	74.380	27.2	46.1	14″×14″ Ingot.	.19	.58	Cold rolled specimen. E=29.700.000
"	"	"	......	51.600	72.050	26.0	41.2	" "			
8/11	4646	20×1⅝	.4989	39.490	74.263	23.3	46.1	....	....	....	Specimen turned round
8/26	"	20×1¼	.5026	43.590	72.120	24.5	50.0	....	...	....	" "
6/11	"	¾ round	......	48.010	72.430	27.0	49.0	14″×14″ Ingot	.25	.82	

PLATES USED IN *TENSION* OR ALTERNATE *TENSION* AND *COMPRESSION.—Continued.*

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8".	Reduction of Area, %	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
6/11	4646	¾ round	......	47.010	72.470	26.3	49.9				
6/20	"	"	......	49.220	78.160	26.2	51.2				
"	"	"	......	49.220	78.160	25.0	51.2				
8/3	4656	24×¾	.5464	41.910	72.969	23.8	42.3				
"	"	"	.6318	42.292	71.747	23.8	42.4				
6/20	"	¾ round	......	51.620	73.890	24.5	41.4	14"×14" Ingot	.19	.82	Cold rolled specimen.
"	"	"	......	51.230	73.770	25.0	41.6	"			
7/29	4645	16×13/16	.5635	42.462	71.418	26.0	45.9				
8/3	"	21×⅝	.5345	45.444	71.693	21.9	46.8				
8/4	"	24½×⅝	.5354	42.305	75.327	21.5	53.1				
6/11	"	¾ round	......	47.720	72.170	24.9	46.0	14"×14" Ingot	.20	.76	
"	"	"	......	47.750	72.680	26.7	48.8	"			
8/25	4731	24×11/16	.4256	46.452	70.065	21.0	56.2				
9/8	"	15×¾	.6046	43.010	69.832	27.5	56.0				
7/22	"	¾ round	......	54.200	73.910	26.4	55.2	14"×14" Ingot	.20	.68	E=31.160.000
"	"	"	......	51.340	71.290	26.8	47.0	"			
8/25	4738	16×9/16	.3733	47.300	70.580	25.0	52.0				
"	"	"	.3699	42.824	68.400	26.0	52.2				
9/8	"	"	.4510	44.094	69.660	24.5	53.1				
"	"	"	.4521	43.970	69.710	25.0	56.1				
"	"	16×⅝	.5147	38.800	66.923	21.3	57.8				
7/30	"	¾ round	......	43.490	68.810	27.3	58.0	....	.19	.74	
"	"	"	......	45.060	68.840	27.3	58.6				
8/25	4728	13½×⅝	.4174	44.682	71.750	23.8	47.9				
7/22	"	¾ round	......	50.070	78.140	24.9	49.5	14"×14" Ingot	.26	.75	Cold rolled specimen. E=30.190.000
"	"	"	......	48.990	77.010	23.0	44.3	"			
9/8	4772	11⅛×11/16	.5095	38.760	69.275	25.0	55.8				
"	"	8½×⅝	.6150	41.835	76.995	23.5	50.9				
"	"	8½×⅞	.4693	43.895	75.860	22.5	53.5	....	....	....	Specimen turned round
8/6	"	¾ round	......	48.980	72.420	22.3	38.5	....	.20	.85	
"	"	"	......	48.830	72.550	24.0	38.3				
"	"	"	......	48.630	72.720	23.0	40.2				
"	"	"	......	48.500	73.290	24.5	39.8				
9/8	4774	17×¾	.5964	41.752	70.004	26.3	53.0				
8/6	"	¾ round	......	48.480	75.620	24.5	42.2	....	.23	.78	
"	"	"	......	48.290	75.590	22.5	41.1				
12/4	4868	11×⅝	.6100	45.490	73.755	26.5	58.9				
9/28	"	¾ round	......	49.330	74.650	23.8	49.7	....	.21		
"	"	"	......	49.350	74.720	25.0	51.6				
10/13	4780	16×⅝	.5608	42.740	75.250	23.8	46.3				
8/10	"	¾ round	......	49.920	76.520	22.5	39.2	....	.24	.84	
"	"	"	......	50.820	76.560	21.9	41.3				
8/26	4662	20×13/16	.4717	44.240	73.140	25.0	56.7	....	....	....	Specimen turned round
6/20	"	¾ round	......	46.400	72.520	26.0	53.8	14"×14" Ingot	.20	.73	
"	"	"	......	46.400	72.320	25.2	54.0	"			

PLATES USED IN *COMPRESSION*—½ INCH THICK AND UNDER.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
6/12	4336	15×⅜	......	52.200	82.470	17.5	30.3	180° round ⅝″	....	....	Blow hole in center surrounded by granular specks.
4/20	"	"	......	51.044	88.180	16.5	43.9	180° " ⅞″			
4/28	"A	13¾×⅜	......	52.547	78.890	22.5	45.6	175° " ⅞″	....	....	
"	"B	"	......	51.800	85.570	18.0	23.9	180° " ¾″			
2/	"	¾ round	......	48.300	86.170	20.6	34.0	....	.38	.71	Test by Fairbanks, Phila. (F)
2/	"	"	......	......	85.980	22.8	32.7	....	....	....	Test at Union Iron Mills, Pittsburgh (U)
2/12	"	"	......	52.850	86.580	20.7	37.6	....	....	....	Test at Penna. S. Co., Steelton. (S)
4/27	4341	14×⅜	.3148	57.115	92.470	18.3	46.5	178° round ⅞″			
2/	"	¾ round	.....	48.206	84.035	23.2	40.4	....	.31	.79	(F)
2/	"	"	......	......	85.650	23.3	37.9	....	....	....	(U)
2/12	"	"	......	52.000	86.740	21.9	40.3	....	....	....	(S)
6/12	4342	15×⅜	.3770	52.060	81.430	20.5	46.9	180° round ½″			
2/	"	¾ round	.....	51.915	82.264	15.6	22.9	....	.34	.81	Broke in punch marks. (F)
2/	"	"	......	......	81.200	23.2	34.2	....	....	....	(U)
2/12	"	"	......	53.720	82.720	22.3	45.6	....	....	....	(S)
4/27	4348	12×5/16	.2648	47.810	85.275	18.0	48.8				
5/8	"	11×⅜	.3307	56.120	83.156	20.3	45.7				
2/	"	¾ round	......	49.210	85.328	22.0	42.6	....	.31	1.02	(F)
2/	"	"	......	55.180	84.960	21.5	38.2	....	....	....	(S)
8/11	4527	15×⅜	.3825	49.726	86.280	18.0	47.2				
4/20	"	¾ round	......	52.860	83.640	21.3	40.3	14″×14″ Ingot	.29	.79	
4/20	"	"	......	53.480	83.420	21.8	38.1	" "			
4/21	"	"	......	50.810	79.260	19.0	49.9	" "	....	....	Specimen annealed.
8/11	4540	13×5/16	.3068	49.480	77.120	22.0	51.3				
"	"	16×½	.4885	50.890	85.142	19.3	50.9				
4/20	"	¾ round	......	54.060	85.980	23.0	46.4	14″×14″ Ingot	.35	.77	
"	"	"	......	53.080	85.080	23.0	44.5	" "			
6/12	4532	15×⅜	.4750	53.537	84.950	21.5	37.2	180° round ⅝″			
	"	8¾×7/16	......	51.670	85.580	20.0	51.6				
7/17	"	11×7/16	.4108	46.005	83.730	21.0	51.0				
6/26	"	9×9/16	.5232	50.360	83.330	21.3	44.4	180° round ¾″			
5/	"	¾ round	......	54.000	85.780	21.3	44.8	No. 1 20″×20″ Ingot			
"	"	"	......	53.070	86.300	23.2	44.8	" "			
"	"	"	......	53.930	83.760	24.6	56.4	" No. 2			
"	"	"	......	54.720	83.420	24.0	54.7	" "			
4/20	"	"	......	53.950	82 500	23.0	52.0	14″×14″ Ingot	.33	.79	
"	"	"	......	54.770	82.740	24.3	49.5	" "			
4/21	"	"	......	49.230	77.580	19.8	58.3	" "	....	....	Specimen annealed.
5/8	4533	15×½	.4343	48.880	83.810	20.0	50.3	180° round ½″			
"	"	"	.4395	48.123	85.440	21.5	47.9	" " ⅝″			
6/12	"	"	.4882	46.300	77.370	17.0	32.3	" " "	....	....	Broke in flaw.
5/8	"	15×⅜	.3541	55 916	87.550	20.8	46.1	" " ⅞″			
4/20	"	¾ round	......	52.530	82.980	23.0	45.3	14″×14″ Ingot	.35	.83	
"	"	"	.....	53.525	84.100	22.5	44.9	" "			
4/21	"	"	......	49.690	80.170	22.0	51.2	" "	....	....	Specimen annealed.
6/25	4539	14×⅜	.3814	50.000	83.000	20.0	36.0	175° round ⅝″			
4/28	"	¾ round	......	51.880	80.830	23.3	48.1	14″×14″ Ingot	.34	.78	
"	"	"	......	51.910	80.660	23.9	48.1	" "			
6/26	4542	14×⅜	.3994	47.770	81.300	18.8	53.8	180° round ⅞″			
"	"	"	.3704	50.000	80.720	20.3	51.2	" ¾ "			
4/28	"	¾ round	......	55.970	86.140	22.3	46.5	14″×14″ Ingot	.37	.85	
"	"	"	......	54.380	86.060	23.0	45.1	" "			
6/25	4546	8×⅜	.3561	48.360	82.100	19.0	45.9	180° round ¾″			



PLATES USED IN *COMPRESSION*.—*Continued.*

Date, 1885.	Heat No.	Specimen cut from,	Area of Specimen,	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength; Pounds per Sq. Inch.	Elongation, % in 8″,	Reduction of Area. %.	Bending and Ingot Note-,	Carbon.	Manganese.	Remarks.
4/28	4546	¾ round	......	51.060	81.280	23.8	47.6	14″×14″ Ingot	.34	.77	
"	"	"	......	50.800	80.320	24.8	46.2	" "			
8/11	4547	20¼×⅜	.3645	51.083	79.010	23.3	55.8				
8/25	"	"	.3664	55.500	79.635	20.3	56.3				
6/12	"	20×5/16	.3048	51.900	75.555	22.5	38.3	180° round ⅜″	...	....	Broke in surface flaw.
5/26	"	"	.2822	52.000	80.000	22.0	54.4				
4/28	"	¾ round	......	53.770	85.620	22.6	45.7	14″×14″ Ingot	.35	.90	
"	"	"	......	55.400	86.040	22.3	47.2	"			
6/12	4548	20×⅜	.3712	50.760	80.000	22.0	39.3				
4/28	"	¾ round	......	49.220	78.520	24.5	50.2	14″×14″ Ingot	.36	.78	
"	"	"	......	49.300	79.440	23.6	50.2				
6/12	4550	20×5/16	.3409	54.970	85.680	15.0	33.1	....	...	.	Broke in surface flaw.
4/28	"	¾ round	......	50.560	79.350	24.9	47.7	14″×14″ Ingot	.34	.79	
"	"	"	......	50.120	79.200	23.5	47.7	"			
6/26	4559	14×7/16	.3973	50.170	82.380	21.2	50.0	180° round ¾″			
"	"	18×7/16	.3927	49.230	80.520	22.0	40.0	" round ⅞″			
8/25	"	14×⅜	.2920	52.290	84.078	23.3	52.3				
7/3	"	18×7/16	.4409	50.830	81.991	23.3	44.6	180° round ¾″			
"	"	"	.3925	53.660	83.580	19.5	28.6	" round ⅞″			
"	"	14×½	.4516	50.000	76.390	23.3	46.3				
5/5	"	¾ round	......	52.925	80.870	22.2	45.8	14″×14″ Ingot	.36	.70	
"	"	"	......	52.080	81.380	22.9	49.1	"			
8/25	4603	19×½	.3861	48.150	80.290	21.0	56.7				
"	"	22½×½	.3911	47.070	80.150	24.5	55.7				
5/25	"	¾ round	......	56.010	81.420	23.6	48.3	14″×14″ Ingot	.25	.88	
"	"	"	......	55.360	81.340	24.3	51.2	"			
8/17	4668	16×7/16	.3161	55.330	86.088	22.5	55.4				
9/8	"	15×⅜	.2983	56.755	83.473	23.5	52.9				
6/11	"	¾ round	......	55.430	88.040	21.9	41.1	14″×14″ Ingot	.35	.80	
6/30	"	"	......	54.590	88.120	22.2	48.4	"			
7/1	4618	26×⅜	.3351	58.000	89.950	16.3	43.9	165° round ⅞″			
"	"	21×⅜	.3172	58.640	91.740	17.5	44.4	180° round ⅝″			
"	"	15×⅜	.3375	58.666	89.900	13.0	47.8	180° round ⅞″			
6/25	"	"	.3853	54.800	86.400	22.0	51.5	180° round ⅝″			
5/25	"	¾ round	......	54.260	86.260	24.5	48.1	14″×14″ Ingot	.33		
"	"	"	......	55.660	86.740	23.3	48.7	"			
8/11	4647	16×7/16	.4244	44.415	85.510	20.8	51.0				
6/11	"	¾ round	......	48.810	82.380	20.5	34.4	14″×14″ Ingot	.38	.93	
"	"	"	......	49.420	82.500	21.1	41.1	"			
6/5	"	"	......	51.825	84.760	23.1	39.4	"			
"	"	"	......	51.740	86.040	20.7	42.4	"			
12/4	4901	14×⅜	.4990	50.260	78.160	21.3	56.6	180° round ⅝″			
10/22	"	12×⅜	.3149	43.350	85.600	17.8	52.3	....	....	....	Broke near jaw.
"	"	14×⅜	.4349	48.290	83.580	19.4	50.0				
10/22	4600	14×½	.4259	43.908	82.030	23.0	51.2				
"	"	"	.4311	49.685	81.035	20.0	51.8				
10/9	"	¾ round	......	59.100	83.880	22.4	42.3				
"	"	"	......	56.940	82.200	24.1	44.5				
12/9	4601	14×½	.4990	50.415	82.664	22.0	55.8	175° round ⅝″			
10/24	"	15×⅜	.3459	51.460	84.800	22.5	52.0				
10/9	"	¾ round	......	54.080	82.700	22.6	39.9		.32		
"	"	"	......	54.700	82.260	21.1	37.9				
10/13	4543	11×⅜	.3380	55.030	84.900	20.5	47.6				
"	"	"	.3365	49.600	80.000	21.3	50.6				
4/20	"	¾ round	......	54.125	81.500	23.0	45 6		.32	.64	
"	"	"	......	53.900	84.320	22.5	45 0				
10/15	4651	13×⅜	.3422	50.906	81.240	20.3	54.2				
10/18	"	"	.3340	51.290	81.740	18.0	47.2				
6/11	"	¾ round	......	48.810	82.180	21.4	53.2	14″×14″ Ingot	.34	.85	
"	"	"	......	52.050	82.620	23.8	50.2	"			
10/26	"	20×7/16	.3784	43.410	74.260	23.0	51.9				
"	"	15×½	.4337	45.420	80.820	18.8	53.5				

PLATES USED IN *COMPRESSION*—OVER ½ INCH THICK.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inches.	Ultimate Strength: Pounds per sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
8/11	4527	20×⅝	.4495	47.936	83.575	18.8	49.4				
8/17	"	"	4419	49.715	83.910	22.5	41.8				
4/20	"	¾ round	......	52.860	83.640	21.3	40.3	14″×14″ Ingot	.29	.79	
"	"	"	......	53.480	83.420	21.8	38.1	"			
4/21	"	"	......	50.810	79.260	19.0	49.9	"	....	....	Specimen annealed.
5/26	4543	20×⅝	.4587	47.960	75.430	24.5	54.3	180° round ⅜″			
4/28	"	¾ round	......	54.125	84.500	23.0	45.6	14″×14″ Ingot	.32	.64	
"	"	"	......	53.900	84.320	22.5	45.0	"			
5/26	4538	20×¾	.5031	49.000	80.000	21.3	47.1	180° round ⅝″			
4/28	"	¾ round	......	52.225	80.000	22.3	46.3	14″×14″ Ingot	.32	.95	
"	"	"	......	53.680	79.920	24.6	45.3	"			
"	4539	20×⅝	.4471	48.535	76.160	25.0	53.3	180° round ½″			
5/26	"	¾ round	......	51 880	80.830	23.3	48.1	14″×14″ Ingot	.34	.78	
4/28	"	"	......	51.910	80.660	23.9	48.1	"			
8/11	4540	20×11/16	.5065	46.000	79.064	16.3	22.6	....	....	....	Broke in bad surface [flaw.
5/26	"	20×¾	.5058	48.616	79.700	22.0	45.8	180° round ½″			
4/20	"	¾ round	......	54.060	85.980	23.0	46.4	14″×14″ Ingot	.35	.77	
"	"	"	......	53.080	85.080	23.0	44.5	"			
5/26	4542	20×11/16	.5425	50.690	84.516	19.5	42.3	175° round ¾″			
4/28	"	¾ round	......	55.970	86.140	22.3	46.5	14″×14″ Ingot	.37	.85	
"	"	"	......	54.380	86.060	23.0	45.1	"			
6/12	4546	20×9/16	.5361	44.450	75.360	24.5	44.1	180° round ⅝″			
5/26	"	"	.4562	50.200	79.130	22.0	42.0	181° round ¾″			
"	"	20×11/16	.5192	48.151	79.160	24.3	45.1	180° round ⅝″			
4/28	"	¾ round	......	51.060	81.280	23.8	47.1	14″×14″ Ingot			
"	"	"	......	50.800	80.320	24.8	46.2	"	.34	.77	
5/26	4547	20×⅝	.4557	47.730	76.256	25.5	51.6	180° round ½″	....	....	Plate punched soft in spots.
"	"	20×9/16	.4066	49.980	76.000	25.5	51.1	"			
10/3	"	20×⅝	.4719	50.070	80.000	25.0	58.3				
4/28	"	¾ round	......	53.770	85.620	22.6	45.7	14″×14″ Ingot	.33	.90	
"	"	"	......	55.400	86.040	22.3	47.2	"			
8/11	4651	20×⅝	.4481	49.023	85.463	20.5	43.8				
8/25	"	"	.4278	49.674	81.346	23.3	49.6				
8/26	"	20×¾	.4604	51.324	83.615	18.5	40.8				
6/11	"	¾ round	......	48.810	82.180	24.4	53.2	14″×14″ Ingot	.34	.85	
"	"	"	......	52.050	82.620	23.8	50.2	"			
8/11	4665	20×9/16	.5537	50.568	81.425	22.5	41.6				
8/17	"	"	.4027	53.710	84.350	23.8	46.6				
"	"	20×⅝	.4484	50.235	83.868	18.0	46.4				
"	"	20×¾	.4384	52.805	88.135	19.8	47.8				
"	"	20×15/16	.3371	55.681	85.170	23.8	53.3				
6/11	"	¾ round	......	53.730	84.740	22.9	38.6	14″×14″ Ingot	.30	.69	
6/30	"	"	......	52.450	84.840	22.5	47.0	"			
8/11	4603	20×¾	.5510	49.095	79.781	22.0	49.3				
8/17	"	"	.5312	45.180	80.230	22.5	47.4				
8/25	"	11×⅝	.4501	41.118	82.975	22.0	48.9				
5/25	"	¾ round	......	56.010	81.420	23.6	48.3	14″×14″ Ingot	....	.88	
"	"	"	......	55.360	81.340	24.3	51.2	"			
8/25	4618	20×11/16	.4556	50.085	84.870	20.5	49.0				
5/25	"	¾ round	......	54.260	86.260	24.5	48.1	14″×14″ Ingot	.33		
"	"	"	......	55.660	86.740	23.3	48.7	"			
8/11	4642	20×9/16	.5516	47.135	82.218	16.3	34.9				
8/17	"	"	.4879	51.180	87.598	22.5	37 7				
6/29	"	¾ round	......	50.360	80.170	25.2	51.3	14″×14″ Ingot	.34	.91	
"	"	"	......	50.340	80.100	25.7	51.4	"			
8/11	4647	16×⅝	.6115	48.082	80.874	20.0	42.0				
8/17	"	20×9/16	.4965	51.620	84.830	21.3	46.1				
"	"	20×¾	.4365	52.760	89.825	23.0	46.1				
6/11	"	¾ round	......	48.810	82.380	20.5	34.4	14″×14″ Ingot	.38	.93	
"	"	"	......	49.420	82.500	21.1	41.1	"			
6/5	"	"	......	51.825	84.760	23.1	39.4	"			
"	"	"	......	51.740	86.040	20.7	42.4	"			
8/11	4668	20×⅝	.4507	56.062	88.010	20.8	42.8				

6/11	4668	¾ round	......	55.830	88.040	21.9	41.1	14"×14" Ingot	.35	.80	
6/30	"	"	......	54.590	88.120	22.2	48.1	"			
12/9	4900	11×⅝	.6162	50.265	81.100	23.0	53.4	181° round 1"			
10/9	"	¾ round	......	59.100	83.880	22.4	42.3				
"	"	"	......	56.940	82.200	24.1	44.5				
12/9	4901	12×⅝	.6200	51.950	80.646	24.5	46.4	180° round ⅞"			
10/9	"	¾ round	......	54.080	82.700	22.6	39.9	... .	.32		
"	"	"	.. ..	54.700	82.260	21.1	37.9				
10/26	4876	22×$^{9}/_{16}$	.4931	46.500	81.630	22.0	50.4				
7/28	"	¾ round	......	55.050	80.410	22.5	40.4	... .	.37		
"	"	"	......	55.300	80.410	22.0	39.5	....	"		

The following tests were made on plates, the steel slabs for which were obtained at Johnstown and plates rolled at Carnegie's.

In these specimen tests and others given later for ¾" rounds on ingots cast by Cambria Iron Co., the work done on the test bars was as follows: Ingots generally 18" square. Heated and rolled to 7" square blooms. A piece cut from bloom and heated, then hammered to 3" square billet,—again heated and rolled to ¾" round bar and then tested without further work.

In the case of the 36" plates, tests on which immediately follow, the ingots were 28"x12" and broken down and spread into 36½"x5" slabs under the hammer.

Considerable difficulty was at first experienced in getting good plates of such unusual size and weight, but extra care in preparation and inspection of the slabs, finally resulted in most satisfactory results.

PLATES USED FOR ALTERNATE *TENSION* AND *COMPRESSION*—OVER ½ INCH THICK.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8".	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
7/9	6329	36×⅝	.4156	50 530	76.516	19.5	30.0				
"	"	¾ round	......	47.180	76.320	21.0	42.0	....	.27	.72	
"	"	"	......	47.450	75.910	22.1	43.3	....	...	...	E=28.970.000.
"	6436	36×⅝	.4286	49.580	73.610	18.8	41.9				
"	"	¾ round	......	48.610	76.250	22.1	42.4	.. ..	.30?	.61	
"	"	"	......	48.960	77.940	23.1	44.6	....	....	....	E=29.470.000.
"	6444	36×⅝	.4012	48.930	72.333	17.5	40.9				
"	"	¾ round	......	49.090	71.800	20.7	40.4	....	.25	.60	
"	"	"	......	49.050	72.070	22.5	38.6				
"	6466	36×⅝	.4032	44.643	70.000	19.5	40.0				
"	"	¾ round	.. ..	57.200	75.180	20.3	45.2	....	.22	.52	Specimen very cold rolled.
"	"	"	.... ..	57.650	75.410	21.0	45.2	....	....	....	"
"	6476	36×⅝	.4265	49.355	77.490	17.0	27.2				
"	"	¾ round	.. ..	49.210	73.810	21 8	39.4	....	.20	.67	
"	"	"	......	49.620	74.400	20.3	31.2	....	....	....	E=29.840.000.
10/18	6676	36×⅝	.5810	46.690	70.220	21.3	55.4				
9/13	"	¾ round	......	47.420	74.920	24.3	44.1	18"×18" Ingot.	.20	.83	
"	"	"	......	47.420	74.920	25.7	45.1	"	.. .	....	=30.080.000.

PLATES USED IN *COMPRESSION*—OVER ½ INCH THICK.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8".	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
9/9	6587	36×$^{11}/_{16}$	.5985	49.575	83.520	22.0	40.6				
7/30	"	¾ round	......	54.730	85.760	18.1	37.9	....	.34	.78	
"	"	"	......	54.500	84.650	19.6	34.7	....	....	....	=30.030.000.

The following tests are for Cambria steel.

In that rolled by the Cambria Company the work done on angles was as follows: Ingots generally 18″ square bloomed down to 7″x7″ for angles under 6″ x4″ and to blooms 7″x8″ for 6″x4″ and 6″x6″ angles.

In angles rolled by the New Jersey Steel and Iron Company, at Trenton, for draw span, the ingots were hammered into billets as follows: 6″x6″ and 6″x4″ angles—billets 9½″x5″; 3½″x3½″ and 3″x3″ angles—billets 4½″x4″; 2½″x2½″ angles—billets 3½″ square.

In column headed *ingot* will be noticed the fact, that some tests were made from 7″ square ingots cast for test ingots.

This method of ascertaining the quality of whole heat was soon abandoned as unjust, both to the mill and purchaser, inasmuch as the results obtained did not give a fair judgment.

In column headed *where tested*, the letters have the following significance.

A—tested at shops at Athens.
C— " Cambria mill at Johnstown.
T— " shops at Trenton.
P— " Olsen's at Philadelphia.

CAMBRIA STEEL, ROLLED BY CAMBRIA COMPANY—ANGLES USED IN *COMPRESSION.*

Date.	Heat No.	Specimen cut from.	Area of Specimen: Sq. Inches.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Where Tested.	Size Ingot.	Carbon.	Manganese.	Bending and Modulus.	Remarks.
7/21	6034	3×3×5/16	.363	46.800	86.200	18.5	42.1	A	....	...	...	180°rd ¼″	½ silky cup.
"	"	3×3×⅜	.325	44.300	83.400	19.4	43.7	A	....	...	...	180°rd ¾″	Full " "
3/	"	¾ round	....	47.260	82.560	21.7	38.6	C	7″ sq.	.35	.52		
"	"	"	....	49.400	83.490	21.1	38.8	C	"				
4/24	"	"	....	47.900	82.520	22.1	46.8	C	18″ sq.	...	...	....	Flat cup silky.
"	"	"	....	47.680	82.080	19.5	46.8	C	"	...	...	28.680.000	" " "
7/21	6038	2½×2½×⅜	.347	44.100	79.200	19.6	44.1	A	... ...	...	...	180°rd ¾″	Full " "
3/	"	¾ round	....	49.790	81.360	19.8	31.7	C	7″ sq.	.34	.49	•	
"	"	"	....	49.960	82.100	18.7	34.6	C	"				
4/22	"	"	....	46.430	79.320	20.5	46.3	C	18″ sq	...	...	....	Regular silky.
"	"	"	....	49.060	83.000	21.2	45.2	C	"	...	...	30.730.000	Irreg. "
"	"	"	....	47.100	81.140	22.7	45.7	C	"	...	...	....	Fine cup "
"	"	"	....	47.100	80.680	23.2	45.6	C	"	...	...	29.610.000	Irreg. "
7/21	5756	4×4×9/16	.562	41.460	75.300	22.5	34.7	A	....	...	...	180°rd 1¼″	Part cup " trace crystals.
7/22	"	4×4×11/16	.555	41.100	78.100	24.4	50.3	A	.... ..	...	...	180°rd 1¼″	Part cup silky trace crystals.
3/	"	¾ round	....	49.350	78.320	20.6	34.9	C	7″ sq.	.33	.53		
"	"	"	....	49.350	78.090	20.4	39.2	C	"				
4/23	"	"	....	48.030	81.600	19.7	34.2	C	18″ sq.	...	...	....	½ cup silky.
"	"	"	....	47.800	81.180	22.0	34.5	C	"	...	...	29.680.000	" " "
7/21	6007	6×4×½	.485	41.600	82.500	23.1	46.9	A	....	...	...	....	Part " " trace crystals.
"	"	"	.491	43.800	38.900	22.4	46.2	A	......	...	...	....	½ cup silky.
"	"	6×4×9/16	.597	42.900	85.600+	....	....	A	....	...	...	....	Not broken.
3/	"	¾ round	...	47.720	85.310	20.0	36.8	C	7″ sq.	.36	.61		
"	"	"	....	50.180	85.060	18.7	35.7	C	"				
4/22	"	"	....	49.560	87.660	20.9	45.5	C	18″ sq.	...	...	....	Flat cup silky
"	"	"	....	49.260	86.950	21.6	45.8	C	"	...	...	28.910.000	" " "
5/4	"	"	....	45.420	83.530	22.5	43.5	C	"	...	...	....	Irreg. silky some crystals.
"	"	"	..	46.470	83.740	21.7	42.3	C	"	...	...	....	Irreg. silky.
10/22	6563	6×4×70 lbs L	.595	45.500	84.030+	9.	8.4	A	....	...	...	180° rd 2″	Could not break.

TESTS OF ANGLES USED IN *COMPRESSION.—Continued.*

Date.	Heat No.	Specimen cut from.	Area of Specimen: Sq. Inches.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch:	Elongation, % in 8″.	duction of Area, %.	Where Tested.	Size Ingot.	Carbon.	Manganese.	Bending and Modulus.	Remarks.
7/23	6563	¾ round	....	58.170	87.830	18.8	39.2	C	18″ sq.	.32	.89	....	Irreg. silky.
"	"	"	....	58.170	88.280	20.3	40.6	C	"	...	...	29.450.000	" "
10/22	6532	4×4×53.5lb. L	.503	38.100	73.300	26.4	53.7	A	....	...	...	180° rd 2″	⅜ cup silky.
7/13	"	¾ round	....	51.250	79.540	22.5	41.9	C	......	.29	.71	....	Silky.
"	"	"	....	52.410	78.840	23 8	44.9	C	....	...	...	29.440.000	"
10/22	6047	4×4×7/16 L	.430	43.500	87.400	19.0	43.5	A	....	...	...	180° rd 1″	¾ cup silky.
3/	"	¾ round	....	51.360	85.760	20.7	33.8	C	7″ sq.	.37	.81		
"	"	"	...	52.320	86.460	19.3	34.0	C	"				
4/22	"	"	....	51.520	85.550	22.2	43.8	C	18″ sq.	...	...	....	Very irreg.
"	"	"	....	51.780	86.000	22.2	42.8	C	"	...	...	31.200.000	Flat cup silky.
10/22	6525	3×3×⅜ L	.373	47.900	85.000	21.3	31.7	A	....	...	..	....	¾ " "
7/10	"	¾ round	....	53.510	86.480	19.0	33.8	C	18″ sq.	.36	.89	....	Crystalline & laminated.
"	"	"	....	53.740	87.180	21.6	33.8	C	"	...	...	30.000.000	Crystalline & laminated.
10/22	6560	2¼×2¼×5/16 L	.323	47.300	81.600	21.3	43.0	A	....	...	...	180°rd ⅜″	½ cup silky.
"	"	"	.314	47.400	84.400	20 3	36.6	A	......	...	...	170°rd ½″	¾ " "
"	"	2¼×2¼×20 lbs	.402	46.000	83.600	21.3	34.1	A	....	...	...	180°rd ¾″	½ " "
"	"	"	.386	45.800	84.200	22.5	43.8	A	....	...	...	180°rd ½″	¾ " "
7/22	"	¾ round	....	53.600	85.800	22.3	42.1	C	18″ sq.	.31	.87	....	Perf. cup "
"	"	"	....	53.450	84.400	21.0	42.2	C	"	...	...	31.520.000	" " "
7/21	6266	2¼×2¼×5/16 L	.295	49.500	81.300	17.5	40.0	A	... ...	...	...	180° rd 1″	Rag'd " "
4/23	"	¾ round	....	47.870	80.480	22.0	48.0	C	18″ sq.	.28	.85		
"	"	"	....	47.870	80.000	23.0	47.6	C	"	...	...	29.440.000	Perf. " "

CAMBRIA STEEL, ROLLED AT TRENTON—ANGLES USED IN COMPRESSION.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Where Tested.	Ingot.	Carbon by Cambria.	Manganese.	Remarks.
	6780	3½″L28.9 lbs	....	46.630	84.610	16.0	18.8	T	....	.33	....	80% cryst-sq.
	"	" "	....	46.960	83.750	19.5	40.0	T	....	.30	.. .	Silky cupped.
	"	" "	....	47.210	82.770	23.5	51.7	C	....	.32	....	" "
	"	" "	....	46.160	81.940	22.7	49.7	C	....	.. .	....	" faint cryst.
	"	" "	....	47.050	85.280	18.2	32.4	T	....	.30	....	" angular.
	"	" "	....	49.140	83.390	20.0	49.4	C	....	.31	....	"
	"	" "	...	46.020	81.580	22.1	47.5	C	....	....	....	"
	"	2½″L14 2 lbs	....	45.170	80.000	18.0	....	T	....	....	....	" angular.
	"	" "	....	46.200	82.500	18.7	44.3	T	....	....	....	" cupped.
9/29	"	¾ round	....	54.060	84.880	21.2	38.1	C	7″ sq. ingot	.32	.82	" ½ cup.
"	"	"	....	54.060	84.880	21.9	38.1	C	"	....	....	" irregular. E=30.160.000.
	6782	2½″L-14.2 lbs	....	46.860	82.830	18.7	41.5	T	....	...	....	Silky cupped.
9/30	"	¾ round	....	50.920	83.540	21.6	44.0	C	14″ sq. ingot	.32	.66	" irregular.
"	"	"	...	51.510	82.870	21.8	43.8	C	"	....	....	" " E=30.380.000.
10/26	6781	3⅛″L-27 lbs	.400	41.250	78.500	23.5	43.8	T	....	....	....	Silky cupped.
"	"	"	.389	43.950	80.840	21.9	44.8	T	... .	....	....	" "
9/30	"	¾ round	....	49.800	80.580	22.1	44.2	C	14″ sq. ingot	.32	.67	" "
"	"	"	....	49.800	80.360	21.9	44.2	C	"	....	....	" ½ cup. E=29.-690.000.
11/28	6788	3″L-25 lbs	.362	45.000	82.870	18.8	43.4	P	....	....	....	Silky square.
"	"	" "	.368	46.640	83.460	17.7	37.8	P				
"	"	" "	.370	45.940	83.790	18.0	34.6	P	....	....	....	" cupped.

CAMBRIA STEEL, ROLLED AT TRENTON—ANGLES USED IN COMPRESSION ACCEPTED ON INGOT TESTS AND REJECTED ON FINISHED TESTS.

Test Mark.	Heat No.	Material.	Where Tested.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Carbon by Salom, Phila.	Carbon by Cambria.	Remarks as to Fracture.
F	6741	3½″ L 40 lbs	T	43.720	77.200	21.8	45.9	.35	.31	Silky cupped.
G	"	" "	T	43.650	78.500	18.7	41.5	.38	.32	" square.
1	"	" "	C	42.510	76.150	22.9	49.8	…	.30	" 100%.
1x	"	" "	C	42.050	74.330	21.5	42.5	…	…	" faintly cryst.
C	"	" 37.8 lbs	T	41.100	70.090	22.5	40.0	.25-.245	.20	" at 45°.
I	"	" 40 lbs	T	42.880	83.690	18.7	29.0	.47-.49	.38-.43-.39	Crystalline fine.
3	"	" 37.8 lbs	C	42.300	71.970	23.2	45.2	…	.27	Silky partly.
3x	"	" "	C	44.850	82.920	19.0	26.4	…	…	Square-cryst.
*	"	" 30 lbs	T	41.260	78.030	19.5	38.2	…	…	Silky cupped.
1	"	" 30.5 lbs	T	44.420	75.390	24.2	34.8	…	…	" "
†	"	" "	T	40.080	73.780	22.6	45.1	.31-.31	.30	" "
7	"	" 30 lbs	C	44.090	80.740	21.2	38.5	…	.42	" ½ cryst ½.
7x	"	" "	C	45.570	80.710	22.3	36.6	…	…	" ¼ " ¾.
8	"	" "	C	41.880	79.820	20.6	43.2	…	.36	" ½ " ½.
8x	"	" "	C	46.340	81.470	19.5	47.4	…	…	" 100%.
	"	¾ round	C	48.560	78.630	21.8	39.9	…	.28	
	"	"	C	48.560	78.630	23.2	44.1			
H	6740	3½″ L 37.8 lbs	T	45.000	80.000	18.7	34.8	.34	.30	Silky cupped.
E	"	" "	T	45.610	81.570	17.1	35.6	.40	.35	" 9/10-angular.
4	"	" "	C	44.150	79.090	16.4	22.1	…	.34	Square crystalline.
4x	"	" "	C	48.120	90.610	13.7	15.9	…	…	" " 100%.
‡	"	3″ L 30.5 lbs	T	46.630	84.750	16.3	22.4	.45-.49	.47-.32-.465	" "
6	"	"	C	44.200	86.360	15.0	17.1	…	.35	" " "
6x	"	"	C	43.750	77.850	19.3	38.0	…	…	Silky.
	"	¾ round	C	49.720	82.100	21.7	41.0	…	.34	
	"	"	C	50.880	81.640	21.0	41.0			

CAMBRIA STEEL, ROLLED BY CAMBRIA—ANGLES USED IN TENSION, OR ALTERNATE TENSION AND COMPRESSION.

Date.	Heat No.	Specimen cut from.	Area of Specimen: Sq. Inches.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8″.	Reduction of Area, %.	Where Tested.	Size Ingot.	Carbon.	Manganese.	Bending and Modulus.	Remarks.
7/22	6319	2½×2½×⅜	.425	42.800	70.100	21.9	48.2	A	....	..	...	180° round ⅛″	½ cup silky.
5/9	"	¾ round	....	44.970	71.350	22.5	41.4	C	18″ sq.	.20	.83	....	Irregular silky.
"	"	"	...	46.100	71.800	24.8	43.5	C	"	...	...	29.360.000	"
7/21	6332	6×4×69 lbs	.541	36.600	69.600	24.3	50.8	A	....	...	...	180° round 2″	½ cup silky.
"	"	"	.546	38.600	69.800	23.1	42.5	A	....	...	...	180° round 2″	Full cup silky.
5/26	"	¾ round	....	46.110	74.550	22.1	42.5	C	18″ sq.	.26	.94	....	½ cup silky.
"	"	"	....	45.740	73.960	24.1	44.9	C	"	...	...	28.900.000	"
7/22	6388	3×3×⅜	.343	41,400	72.300	24.4	53.3	A	....	..	...	180° round ¾	"
"	"	3×3×5/16	.344	42.400	73.500	22.5	52.0	A	....	...	...	180° round ½	"
5/28	"	¾ round	....	43.240	71.360	25.4	49.7	C	18″ sq.	.23	.73	....	"
"	"	"	....	43.110	70.920	24.7	50.7	C	"	...	...	....	Deep cup silky.
7/22	6259	3×3×21.5 lbs	.349	42.400	73.300	21.0	47.5	A	....	...	...	180° round 1″	½ cup silky.
4/18	"	¾ round	....	43.710	72.700	20.3	41.3	C	18″ sq.	.24	.54	....	Silky.
"	"	"	. ..	45.200	72.500	21.4	40.4	C	"	...	...	....	"
7/22	6270	2½×2½×5/16	.308	45.400	76.400	21.9	52.9	A	....	...	...	180° round 1″	Perf. cup silky.
4/23	"	¾ round	...	45.100	73.460	24.1	44.8	C	18″ sq.	.27	.86	....	½ cup silky.
"	"	"	....	44.870	73.000	23.4	45.8	C	"	...	...	28.830.000	"
7/22	6272	5×3½×⅜	.385	42.600	73.000	24.4	51.9	A	....	...	...	180° round ¾″	Full cup silky.
4/23	"	¾ round	....	45.560	72.850	23.5	43.0	C	18″ sq.	.24	.64	... .	½ cup silky.
"	"	"	....	45.330	72.850	23.8	39.9	C	"	...	...	30.830.000	Silky.
10/22	6571	6×4×69 lbs	.544	39.900	71.200	25.4	53.1	A	....	...	...	180° round 1½	¾ cup silky.
"	"	2½×2½×30 lbs.	.470	40.200	74.700	25.5	51.7	A	....	...	...	180° round 1″	
"	"	2½×2½×30 lbs.	.465	43.200	75.600	26.4	47.7	A	....	...	...	180° round 1½″	¾ cup silky.
7/27	"	¾ round	....	49.390	76.690	23.8	47.9	C	18″ sq.	.24	.94	. ...	Irreg. silky.
"	"	"	....	50.960	76.890	23.2	44.9	C	"	...	...	30.860.000	"
10/22	6555	4×4×53.5 lbs	.518	39.000	77.200	23.4	48.8	A	....	. .	...	180° round 1½	¾ cup silky.
"	"	4×4×33.2 lbs	.404	41.500	78.200	24.0	46.5	A	....	...	...	180° round 1″	½ cup irreg.
7/20	"	¾ round	....	47.980	73.340	24.0	50.1	C	18″ sq.	.20	.88	....	Perf. cup silky.
"	"	"	....	47.290	70.580	24.0	49.1	C	"	...	...	28.830.000	Imp. cup silky.
10/22	6344	3×3×11/16 L.	.510	43.500	77.400	24.0	41.8	A	....	...	...	180° round 1½″	½ cup irreg.
"	"	"	.502	40.100	76.000	23.9	44.4	A	....	...	...	180° round ½	"
5/13	"	¾ round	....	45.570	75.310	23.2	38.6	C	18″ sq.	.24	.41	.. ..	Irregular silky.
"	"	"	....	44.610	73.500	23.2	40.9	C	"	...	...	28.900.000	"
10/22	6570	3×3×7/16 L.	.406	43.100	74.600	20.1	40.9	A	....	...	...	180° round 1″	½ cup silky.
"	"	"	.417	42.200	73.900	23.3	53.9	A	....	...	...	180° round 1″	¾ cup silky.
7/30	"	¾ round	....	46.920	71.790	23.1	46.4	C	18″ sq.	.22	.63	....	½ cup silky.
"	"	"	....	45.750	70.940	24.3	48.5	C	"	...	...	30.260.000	"
10/22	6565	2½×2½×5/16	.313	43.200	71.200	19.8	52.1	A	....	...	...	180° round ½″	½ cup irreg.
"	"	2½×2½×5/16	.309	42.900	70.600	25.6	50.0	A	....	...	...	180° round ¼″	⅝ cup silky.
7/23	"	¾ round	....	46.380	70.740	27.0	53.5	C	18″ sq.	.18	.90	....	Deep cup silky.
"	"	"	....	47.080	70.260	27.5	54.4	C	"	...	...	29.920.000	Irregular silky.
	6730	3½″ L 40 lbs	....	41.340	70.940	26.0	47.6	C	:......	.29			
	"	" " "	....	40.710	70.650	22.3	45.0	C					

CAMBRIA STEEL, ROLLED AT TRENTON—ANGLES USED IN *TENSION*.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen: Sq. Inches.	Elastic Limit: lbs. per Sq. Inch.	Ultimate Strength: Pounds per Sq. In.	Elongation, % in 8".	Reduction of Area, %.	Tested at.	Size Ingot.	Carbon.	Manganese.	Remarks.
11/14	"	3" L 17.7 lbs	.341	42.810	73.630	20.6	41.7	T	....	...	...	Silky at 45°.
"	"	" " "	.352	42.040	70.020	20.3	44.4	T	....	...	...	" cupped.
"	"	" " 25.3	.447	40.940	70.800	23.5	42.6	T	....	...	...	" at 45°.
9/15	"	¾ round	....	45.620	72 550	22.5	51.5	C	14" sq. Ingot	.28	.55	" irregular.
	"	" "	....	47.000	72.550	25.0	52.4	C	"	...	...	Silky irregular E=30.600.000.
11/14	6775	3" L-33.2 lbs	.469	43.710	76.870	21.8	41.0	T	....	...	.	Silky cupped.
9/29	"	¾ round	....	48.180	77.530	22.0	45.5	C	7" sq. Ingot	.25	.95	" partial cup.
"	"	"	....	49.790	77.300	24.2	44 5	C	"	...	...	Silky partial cup. E=30.080.000.
11/14	6776	3" L 33.2 lbs	.478	42.050	72.800	25.0	46.7	T	....	...	...	Silky cup.
9/29	"	¾ round	....	50.470	76.830	24.3	45.5	C	7" sq. Ingot	.22	.90	" partial cup.
"	"	"	....	50.470	76.620	25.5	46.5	C	"	...	...	Silky partial cup. E=30.590.000.
11/14	6785	6"×6"L×⅝"	.464	41.560	70.900	23.8	44.2	T	....	...	...	Silky cupped.
"	"	"	.488	42.820	71.920	23.8	35.3	T	....	...	...	" 9/10-angular.
"	"	6"×4"L×¾"	.530	41.700	70.560	25.0	45.1	T	....	...	...	Silky cupped.
"	"	" "	.547	40.210	70.200	24.0	39.0	T	....	...	...	" "
9/29	"	¾ round	....	47.160	72.750	25.1	48.6	C	14" sq. Ingot	.21	.59	" cup.
"	"	"	....	47.160	71.850	24.2	49.5	C	"	...	...	Silky irregular. E=30.460.000.
11/14	6786	3" L 28.0 lbs	.507	42.010	71.990	20.8	49.3	T	....	...	...	Silky-¾ angular.
10/1	"	¾ round	....	48.920	72.130	22.1	42.9	C	14" sq. Ingot	.18	.83	" irregular.
"	"	"	....	49.610	73.710	23.9	41.9	C	"	...	...	Silk irregular. E=29.600.000.
11/14	6795	3" L-28 lbs	.515	41.300	70.870	18.8	41.6	T	....	...	..	Silky cupped.
10/3	"	¾ round	....	50.260	75.510	21.7	35.0	C	14" sq. Ingot	.24	.72	" irregular.
"	"	"	....	50.970	75.510	23.8	40.0	C	"	...	..	Silky cupped. E=29.690.000.

In the following tests on rivet steel, the first four were made at mill on ¾ round, from ingot.

The other tests were made at shop at Athens on the regular rivet bars. The 3" square billets were rolled into rivet material at Pencoyd Mills. All the rivets tested in this lot came from the heats 4635 and 4637, but as rivet bars had no heat numbers stamped on them they could not be identified closely.

PENNA. STEEL CO.'S STEEL, ROLLED AT PENCOYD—STEEL RIVETS.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8".	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
6/5	4635	¾ round	.500	46.370	61.310	28.5	54.3	18" sq. Ingot.	.10	.40	½ cup silky.
"	"	"	.495	45.700	61.340	26.7	55.1	"			"
"	4637	"	.525	44.550	61.650	27.5	48.7	"	.11	.44	"
"	"	"	.525	43.940	61.650	26.4	48.8	"			"
6/24	....	⅞ round	.594	24.300?	56.230	33.4	64.3				
"	....	"	.603	27.200	59.200	30.0	62.0				
6/26	...	¾ round	.443	25.300?	59.600	30.0	64.1	Specimen not treated.			
"	....	"	.443	28.200	59.140	31.3	64.1	" "			
6/27	....	"	.447	38.500	59.060	28.8	62.9	" reheated then air cooled.			
"	....	"	.445	34.800	57.900	30.0	61.3	" " "			
6/29	....	"	.443	26.840	55.080	29.6	60.9	" annealed.			
"	....	"	.441	26.500	54.400	30.6	63.9	" "			
6/26	....	"	.438	29.200	73.500	15.6	62.1	" heated bright red then quenched in water.			
"	....	"	.439	28.000	74.260	..	....	" " "			broke in jaw.
6/27	....	"	.443	45.100	73.100	15.3	59.1	" " "			
"	....	"	.438	52.050	75.200	....	63.7	" " "			"

BENDING TESTS.

⅞" round Rods—Cherry red—then quenched in water; nicked and bent broke at 60°; without nicking bent double around ⅜" round, no crack.

⅞" round Rods—Bright red—then quenched, bent double around ⅜" round, no crack.

¾" round—2 pieces—Bright red—then quenched, bent double around ⅛" round, no crack.

¾" round—2 pieces—Bright red—then air cooled, bent double around ⅜" round, no crack.

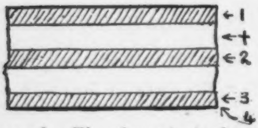
⅞" round—3 pieces—Bright red—then air cooled, bent double around ¼" round, no crack.

When tested with file no perceptible difference detected between quenched and air cooled.

PENNA. STEEL CO.'S STEEL, ROLLED AT PENCOYD—STEEL RIVETS.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8".	Reduction of Area, %.	Bending and Ingot Notes.	Carbon.	Manganese.	Remarks.
8/6	4767	¾ round	.531	42.220	60.610	27.5	49.7	Ingot tests made at Steelton.	.09	.35	
"	"	"	.513	42.380	60.500	28.3	53.3				
"	4769	"	.523	40.870	62.000	27 5	51.1		.08	.43	
"	"	"	.512	41.650	61.840	27.8	53.2				
8/17	4775	"	.496	41.270	63.190	28.5	56.6		.10	.42	
"	"	"	.500	40.750	63.360	28.5	55.6				
"	4777	"	.497	39.260	60.460	29.3	55.9		.09	.35	
"	"	"	.505	38.970	59.670	27.8	54.9				
"	4779	"	.505	38.910	59.750	30.5	55.2		.09	.37	
"	"	"	.497	38.730	59.530	28.8	56.1				
"	4782	"	.475	37.780	58.590	28.8	60.1		.10	.48	
"	"	"	.498	38.250	58.980	28.8	56.1				
8/	....	"	.454	39.000	61.200	28.4	63.4	Rivet bar tests made at Athens.	....	....	Full cup silky.
9/21	....	⅞ "	.605	38.800	59.900	30.8	66.3		...	....	¾ "
"	....	"	.605	37.300	58.200	30.0	67.6		...	....	Full "
"	....	"	.600	35.500	58.400	28.4	68.5		....	....	⅞ "
"	....	"	.597	36.300	58.800	32.6	67.2		....	....	¾

CAMBRIA STEEL, ROLLED BY CAMBRIA—SPECIMEN TESTS ON EYEBAR STEEL.



No. 1. Edge of bar, 1/8″ skin planed off.
" +. Between edge and center.
" 2. Centre of bar.
" 3. Edge of bar, 1/8″ skin planed off.
" 4. Edge of bar, skin left on.

In all specimens width equals thickness of bar, except those marked *, which were turned up round. The four tests from Heat No. 6391, marked *, were from same bar as those immediately preceding.

Date.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit per Sq. Inch.	Ultimate Strength per Sq. Inch.	Elongation, % in 8.″	Reduction of Area, %.	Ingot and Bending.	Carbon.	Manganese.	Mark.	Modulus and Remarks.
7/2	6324	3×3/4	.622	41.480	75.240	23.7	34.7	....	....	....	No. 2	1/3 Crystalline.
"	"	"	.628	41.080	75.160	26.1	46.0	....	....	..	No. 1	Silky.
.....	"	3/4 round	...	47.860	75.910	23.1	43.3	18″×18″ Ingot	.20	.66		
.....	"	"	....	47.720	75.700	22.5	41.4	"	....	....	......	E=30.080.000
7/2	6325	4×13/16	.611	41.700	71.800	23.7	39.6	....	....	....	No. 1	1/4 Crystalline.
"	"	"	.608	40.800	70.560	23.1	45.6	....	....	....	No. 2	Silky.
5/11	"	3/4 round	....	47.590	75.500	22.5	40.6	....	.20	.60	......	
5/11	"	"	....	47.350	75.270	23.0	38.5	....	....	...	......	E=30.260.000
7/2	6339	5×21/32	.484	40.700	75.200	24.4	47.7	180° round 2″	....	...	No. 1	Silky.
"	"	"	.479	43.800	72.900	25.6	41.1	....	....	..	No. 2	1/8 Fine crystal specks.
5/16	"	3/4 round	....	45.820	73.400	23.4	39.3	18″×18″ Ingot	.21	.68		
"	"	"	....	45.330	72.610	22.7	38.7	"	....	....	.....	....E=29.600.000
7/3	6341	5×13/16	.591	42.100	79.300	20.9	22.8	140°-broke.....	....	....	No. 1	7/8 1/8 Silky. Crystalline.
"	"	"	.591	42.600	79.700	19.6	24.3	....	....	....	No. 2	"
5/16	"	3/4 round	....	48.890	78.420	22.0	39.3	18″×18″ Ingot	.22	.87		
"	"	"	....	49.160	78.850	22.4	37.7	"	...	....	.....	E=31.410.000
7/1	6290	6×1	.659	38.550	69.730	26.3	65.5	180° round 1 1/8″	....	....	No. 1	Silky.
"	"	"	.706	36.800	65.650	25.1	56.1	....	....	....	No. 4	"
"	"	"	.611	38 950	76.760	26.3	52.5	....	....	....	No. 2	"
4/29	"	3/4 round	....	43.710	72.700	24.8	45.2	18″×18″ Ingot				
"	"	"	....	45.200	72.500	25.1	45.2	"	....	....	......	E=29.290.000
7/2	6391	7×1 3/8	.592	39.870	77.950	13.3	13.3	140°-broke.....	....	....	No. 2	Broke near jaw. Completely crystalline.
"	"	"	.594	39.900	76.200	12.0	11.8	....	....	....	No. 2	"
"	"	"	.632	37.300	69.940	24.4	38.6	....	...	....	No. 1	60% Crystalline.
"	"	"	.630	36.800	69.290	24.3	44.9	....	....	....	No. 3	30% "
7/7	6391	7×1 3/8	*.444	41.440	77.200	23.1	48.4	150°-broke	....	.. .	No. 1	Fairly silky.
"	"	"	*.448	40.620	76.700	23.0	43.1	....	...	....	No. 3	"
"	"	"	*.445	38.200	72.900	22.3	36.8	....	....	....	No. 2	1/4 Crystalline.
"	"	"	*.445	38.400	72.990	24.5	36.8	....	....	....	No. 2	30% "
6/1	"	3/4 round	......	46.630	77.630	22.7	42.2	18″×18″ Ingot	.27	.55	......	
"	"	"	......	46.170	76.940	21.7	43.2	"	....	....	......	E=28.750.000.
6/23	6473	"	......	49.620	76.990	24.2	43.9	....	.26	.57	......	
"	"	"	......	49.730	75.970	23.6	44.8	....	....	...	......	E=30.170.000.
7/29	6589	"	......	47.910	73.670	23.3	44.8	....	.23	.77	......	
7/30	"	"	.. ...	48.310	74.510	22.8	46.4	....	....	....	......	
6/19	6469	"	......	49.560	74.789	20.9	35.1	18″×18″ Ingot	.25	.58	......	
"	"	"	......	50.470	74.560	20.4	35.1	"	....	....	......	E=29.140.000.
10/8	6794	"	......	46.340	69.750	23.9	44.5	....	.19	.50	......	
"	"	"	......	46.800	69.500	24.8	43.5	....	....	...	......	E=29.840.000.
10/2	6790	"	......	49.160	74 180	22.1	42.9	....	.23	.84	......	
"	"	"	......	49.160	75.100	24.5	42.9	....	....	....	......	E=29.840.000.
6/18	6461	"	......	48.670	69.420	24.0	46.2	18″×18″ Ingot	.20	.57	......	
"	"	"	......	46.820	69.190	25.9	48.1	"	....	....	......	E=30.750.000.

SPECIMEN TESTS ON EYEBAR STEEL.—*Continued.*

Date.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit per Sq. inch.	Ultimate Strength per Sq. inch.	Elongation, % in 8.″	Reduction of Area, %.	Ingot and Bending.	Carbon.	Manganese.	Mark.	Modulus and Remarks.
10/22	6589	6×1⅜	*.499	40.000	73.700	23.8	50.5	........60° b'ke	...	...	....	½ cup silky edges, pitted center
7/29	“	¾ round	.....	47.910	73.670	23.3	44.8	18″ sq.........	.23	.77	....	Irregular silky.
7/30	“	“	.....	48.310	74.510	22.8	46.4	“	...	...	....	“
“	“	“	.....	48.630	74.510	22.4	42.5	“	...	...	29.600.000	“
10/22	2244?	3×¾	†.668	45.400	74.900	9.5	12.1	....	...	...	....	Not broken.
“	“	5×1⅛	*.499	39.100	74.200	26.1	52.7	....	...	...	....	¾ cup silky.
“	“	$7\times1^{7}/_{16}$	†.619	34.900	69.600	27.5	42.2	170° r'd 2′, b'ke	...	...	....	½ “
“	6570	$4\times1^{9}/_{16}$	*.500	38.500	74.700	25.3	56.0	....	...	...	....	⅞ “
7/3	“	¾ round	.....	46.920	71.790	23.1	46.4	18″ sq.........	.22	.63	....	½ “
“	“	“	.....	45.750	70.940	24.3	48.5	“	...	...	30.260.000	“
10/22	6567	$4\times^{13}/_{16}$	*.450	40.200	74.900	25.8	58.9	....	...	...	....	¾ “
7/23	“	¾ round	.....	47.980	75.180	21.3	50.1	18″ sq.........	.24	.91	....	Irregular silky.
“	“	“	.....	48.200	74.950	24.5	49.1	....	...	...	29.760.000	
10/22	6617	3×1¼	†.621	38.500	69.600	26.9	39.4	....	...	...	....	⅙ cup silky.
8/8	“	¾ round	.....	47.530	72.900	24.4	42.2	18″ sq.........	.22	.67	....	Nearly perfect cup, silky.
“	“	“	.....	48.530	72.460	25.5	43.4	“	...	...	29.130 000	“
10/22	6597	6×1⅝	†.552	39.500	74.300	27.3	37.5	180° r'd 1″ b'ke	...	...	....	½ cup silky.
8/1	“	¾ round	.....	45.710	70.330	23.2	40.2	18″ sq..	.20	.57	....	Irregular silky.
“	“	“	.....	46.880	71.030	21.1	40.2	“	...	...	29.530.000	“
10/22	?	$7\times2^{3}/_{16}$	†.626	34.700	64.900	23.1	37.1	Specimen .975×.642			....	⅛ cup, ¼ crystalline on skin edge, remainder pitted.

In the tests for eyebars (table opposite page 128), the full sized bars were ordered to Athens. From each bar a piece 18″ long was cut, from which the specimen tests were planed out with location in bar as shown by sketch and marks carried out against the tests.

Then the long bars were cut in two and eyebars made from them for test. In case of $3''\mathrm{x}\frac{3}{4}''$ and $4''\mathrm{x}\frac{13}{16}''$ bars, this was done with both pieces of bar and in other cases only one eyebar was made from each size. Hence, it will be seen that the chain is complete, viz., $\frac{3}{4}''$ round tests of ingots at mill—specimen tests of the finished bar from outside and center of bar and finally the test of the completed eyebar made from same bar.

It is to be noted that the small eyebars tested at Fairbanks & Co. are off from same original bar as those of same size sent to Edge Moor, although the excesses in sectional area of head are different.

Eyebars No. 1 to No. 6 inclusive, were submitted in accordance with the specifications, and were tested at Edge Moor Iron Works. Eyebars No. 1a and No. 2a were experimental bars sent to Fairbanks & Co. for test by Union Bridge Co., having less excess section in the eyes.

Eye bar No. 7 was a regular eyebar, which when inspected, showed presence of a cold shut in neck and was rejected.

Experiment was made at blacksmith forge to eliminate the defect, and the appearance of the bar indicated that the work was successful. To test the method however, the bar was reannealed and sent to the Keystone Bridge Company and broken, with results shown in table. The inspector was given special instructions to note appearance of repaired spot during and after test, but no defect was detected.

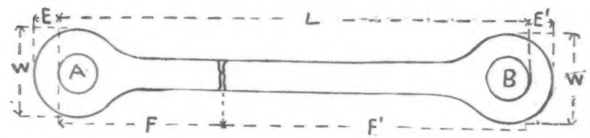
Eyebar No. 8 was a steel lateral bar with upsets and an iron sleeve nut. This bar was not made specially for test.

Eyebars No. 9, No. 10 and No. 11 were selected at random and not made for testing.

The specimen tests given in table from heats 6589, 2244 (?) 6570, 6567, 6617, 6597 and (?) and are on steel, made and used for eyebars of which no full size eye bar tests were obtained.

The following tests show the results of imposing an initial strain of 20,000 lbs. per sq. inch on a car load of eyebars in accordance with specifications. The bars were carefully tested in the Keystone machine. This specification was subsequently waived and no more such tests made.

TESTS ON FINISHED EYEBARS.



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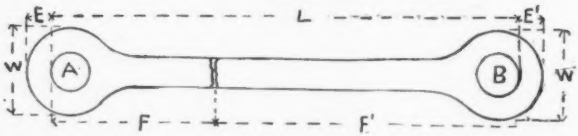
Date, 1885.	Test No.	Heat No.	Before Test. Dimensions. Bar.	Length. L.	Pinhole A.	Pinhole B.	Sectional Areas. Bar.	Eye A. E.	Eye A. W.	Eye A. % Excess.	Eye B. E'.	Eye B. W'.	Eye B. % Excess.	Limit Elasticity: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	After Test. Elongations. Hole A.	Hole B.	Bar. Measured Length.	Bar. Amount.	% in Length L.	Reductions. Area of Fracture Sq. Inch.	% of Original Area.	Fracture. Distance from back of Pinhole F.	Character of Fracture.	Modulus of Elasticity: Pounds.	Remark[s] Origi[nal] Bar[s]
7/29	1	6324	$3\times\frac{3}{4}$	9'-3½"	3.52"	3.52"	2.31	2.05	3.75	62.3	2.16	3.75	62.3	41.700	74.400	0.31"	0.34"	No record	1'-3¼"	13.7	1.28	44.6	3'-3⅛".	½ cup, silky edges	....	Heads planed on sides.
"	2	6325	$4\times\frac{13}{16}$	8'-0 3/16"	5.77	5.77	3.33	2.96	5.07	52.3	3.06	5.08	52.5	42.300	72.100	0.51	0.38	"	0'-11 7/16"	11.5	1.89	43.3	1'-11"	Full cup, silky edges........	....	
"	3	6339	$5\times\frac{31}{32}$	7'-11 11/16"	5.77	5.77	4.95	4.12	7.00	41.4	4.00	7.00	41.4	38.900	71.800	0.58	0.70	"	0'-11 9/16"	12.1	2.89	41.6	1'-6½"	⅓ finely crystalline, ⅔ silky........	....	
"	4	6341	$5\times1\frac{3}{16}$	7'-9 7/16"	6.27	6.27	6.00	5.05	9.20	53.3	4.96	9.21	53.5	44.400	78.500	0.69	0.61	"	0'-11 7/16"	12.2	3.59	40.1	2'-4½.'	Silky cup........	....	
"	5	6290	6×1	6'-6⅛"	7.27	7.27	6.00	4.76	8.77	46.1	4.76	8.70	45.0	38.300	65.400	......	0 54	"	0'-3"	0.4	....	....	....	Eye end opened, coarsely crystalline........	....	
"	6	6391	$7\times1\frac{3}{8}$	7'-9 3/16"	7.27	7.27	9.77	7.32	13.50	38.2	7.24	13.41	37.2	37.900	61.300	0.58	0.65	"	0'-3⅜"	0.4	....	....	....	No fracture........	....	
7/27	1a	6324	$3\times\frac{3}{4}$	9'-2 15/16"	4.52	4.52	2.30	1.71	3.15	37.0	1.72	3.25	41.3	36.601	66.823	0.52	0.48	7'-0"	1'-0¼"	14.6	1.26	45.2	2'-1½"	Fine silky........	28.154.000	
"	2a	6325	$4\times\frac{13}{16}$	8'-1⅜"	6.78	6.78	3.29	2.76	4.87	48.0	2.47	4.74	44.0	36.496	64.720	0.62	0.80	5'-0"	0'-7⅛"	11.8	1.9	42.2	1'-9⅜"	....	30.416.000	
10/17	7	6473	$4\times\frac{15}{16}$	34'-9 5/16"	4.02	5.02	3.75	3.18	5.45	45.3	3.25	5.44	45.1	35.700	63.470	0.56	0.38	20'-0"	2'-2⅝"	12 4	2.69	28.3	2'-5½"	Irregular silky edges........	28.236.000	Heads planed.
1886																										
2/19	8	Long end. 6589	$3\times\frac{13}{16}$	5'-1⅜" 24'-2⅛"	3.02	3.02	2.44	2.48	4.78	95.9	2.48	4.70	92.6	43.200	67.700	0.25	0.19	4'-0"	0'-7¾"	16.1	1.27	48.0	Short end 1'-4½"	Silky cup, showing one separation........	....	Heads not planed.
"	9	6469	$5\times1\frac{1}{16}$	30'-6¾"	5.02	4.52	5.31	4.43	7.44	40.1	4,68	7.44	40.1	41.600	66.400	0.56	0.47	20'-0"	2'-4"	11.7	2.58	51.5	7'-2½"	Silky cup........	....	
"	10	6794	$5\times1\frac{3}{16}$	20'-4"	5.52	5.52	5.94	4.69	9.19	54.7	4.91	10.13	70.5	40.300	64.600	0.63	0.56	16'-0"	1'-11"	11.9	3.07	48.3	7'-10½"	Silky center, fine granular edges........	....	
"	11	6790	$5\times1\frac{5}{16}$	20'-4"	5.52	5.52	6.56	5.80	9.85	50.2	5.68	9.86	50.3	40.000	70.340	0.50	0.38	16'-0"	1'-8¼"	10.5	5.94	9.5	4'-4⅛"	Square across, finely granular throughout..	....	

TESTS ON FINISHED EYEBARS.



B.		Limit Elasticity: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	After Test.								
				Elongations.					Reductions.		Fracture.	
				Hole A.	Hole B.	Bar.		% in Length L.	Area of Fracture Sq. Inch.	% of Original Area.	Distance from back of Pin-hole F.	Character of Fracture.
.	% Excess.					Measured Length.	Amount.					
5	62.3	41.700	74.400	0.31″	0.34″	No record	1′-3¼″	13.7	1.28	44.6	3′-3⅛″	½ cup, silky edges ....
8	52.5	42.300	72.100	0.51	0.38	"	0′-11 7/16″	11.5	1.89	43.3	1′-11″	Full cup, silky edges........................
0	41.4	38.900	71.800	0.58	0.70	"	0′-11 9/16″	12.1	2.89	41.6	1′-6½″	⅓ finely crystalline, ⅔ silky............
1	53.5	44.400	78.500	0.69	0.61	"	0′-11 7/16″	12.2	3.59	40.1	2′-4½.′	Silky cup........................
0	45.0	38.300	65.400	.....	0 54	"	0′-3″	0.4	....	....	....	Eye end opened, coarsely crystalline......
1	37.2	37.900	61.300	0.58	0.65	"	0′-3⅜″	0.4	....	....	....	No fracture........................
5	41.3	36.601	66.823	0.52	0.48	7′-0″	1′-0¼″	14.6	1.26	45.2	2′-1½″	Fine silky............... ....
4	44.0	36.496	64.720	0.62	0.80	5′-0″	0′-7⅛″	11.8	1.9	42.2	1′-9⅜″	....
4	45.1	35.700	63.470	0.56	0.38	20′-0″	2′-2⅝″	12 4	2.69	28.3	2′-5½″	Irregular silky edges........................
0	92.6	43.200	67.700	0.25	0.19	4′-0″	0′-7¾″	16.1	1.27	48.0	Short end 1′-4½″	Silky cup, showing one separation........
4	40.1	41.600	66.400	0.56	0.47	20′-0″	2′-4″	11.7	2.58	51.5	7′-2½″	Silky cup........................
3	70.5	40.300	64.600	0.63	0.56	16′-0″	1′-11″	11.9	3.07	48.3	7′-10½″	Silky center, fine granular edges.........
6	50.3	40.000	70.340	0.50	0.38	16′-0″	1′-8¼″	10.5	5.94	9.5	4′-4⅛″	Square across, finely granular throughout

	Modulus of Elasticity: Pounds.	Remarks on Original Bars.		Remarks on Tested Bars.	Where Tested.
		Heads planed on sides.	Annealed in open air wood fire.		Edge Moor.
				Opened crack ⅛″ deep on end of Eye A	"
					"
				Cold shut in Eye A opened	"
e				Fracture started in initial crack on outside	"
				Machine unable to break	"
	28.154.000				Fairbanks, N. Y.
	30.416.000				"
	28.236.000	Heads planed.	Annealed in furnace wood fire.	Heads showed no cold shuts	Keystone.
		Heads not planed.		Screw threads, 2⅛″ diam., uninjured, sleeve nut easily unscrewed.	"
					"
					"
ghout					"

INITIAL TESTS OF EYEBARS WITHIN THE ELASTIC LIMIT.

Date, 1885.	Mark.	Size of bar.	Length C to C pins.	Size of Pins.		Area of bar.	Pounds strain per sq. in.	Extension in 16′–8″ inches.	Modulus of elasticity.	Remarks.
				A.	B.					
10/9	$L_1 M_1$	4×1	20′–4″	3½	5¾	4.00	20.000	.1355	29 520.000	No permanent set.
"	"	"	"	"	"	"	"	.1363	29.347.000	"
"	"	"	"	"	"	"	"	.1366	29.282.000	"
"	"	"	"	"	"	"	"	.1373	29.133.000	"
10/7	$L_3 M_3$	4×⅞	"	3½	4¾	3.50	"	.1330	30.007.000	"
10/10	"	"	"	"	"	"	"	.1322	30.257.000	"
10/7	$L_5 M_5$	4×⅞	"	3½	4½	3.50	"	.1312	30.490.000	"
10/10	"	"	"	"	"	"	"	.1326	30.167.000	"
"	"	"	"	"	"	"	"	.1390	28.777.000	"
10/7	"	"	"	"	"	"	"	.1367	29.261.000	"
10/8	$L_7 M_7$	$4 \times {}^{27}/_{32}$	"	3½	4¼	3.37	"	.1319	30.327.000	"
"	"	"	"	"	"	"	"	.1315	30.417.000	
10/10	"	"	"	"	"	"	"	.1318	30.349.000	Heat No. 6461. Specimen test E=30,750,-[000.
"	"	"	"	"	"	"	"	.1358	29.456.000	"
10/8	$L_9 M_9$	$4 \times {}^{27}/_{32}$	"	3½	4¼	3.37	"	.1357	29.478.000	"
10/10	"	"	"	"	"	"	"	.1325	30.190.000	"
10/8	$L_{11} M_{11}$	$4 \times {}^{27}/_{32}$	"	3½	4¼	3.37	"	.1305	30.651.000	"
"	"	"	"	"	"	"	"	.1326	30.167.000	"
10/10	$L_{13} M_{13}$	4×⅞	"	3½	4½	3.50	"	.1327	30.143.000	"
"	"	"	"	"	"	"	"	.1350	29.260.000	"
10/7	"	"	"	"	"	"	"	.1337	29.917.000	"
"	"	"	"	"	"	"	"	.1310	30.534.000	"
10/7	$L_{15} M_{15}$	4×⅞	"	3½	4¾	3.50	"	.1328	30.120.000	"
"	"	$4 \times {}^{27}/_{32}$	"	"	"	3.37	"	.1350	29.632.000	

SPECIAL TESTS.

Tests on Full Size Steel Posts.

The following tests were made on posts built from drawings used for members actually in structure.

The "Tension" post was an exact duplicate, as nearly as can be produced in a shop, of four now in the 260 feet anchorage spans, which were proportioned to take alternate tension and compression.

The "Compression" post is the duplicate of the upper section of double length posts used in the Draw span, but, instead of ending at the splice, the latter was put in, and part of lower section extending from splice to center of middle pin was added and the post made flat ended at that end, the half pin hole being omitted.

In the table, the values of modulus of elasticity were computed after receiving the report from Watertown.

POST MADE FROM TENSION STEEL—WEIGHT, 2,062 LBS.

PINS IN HORIZONTAL POSITION.—PLATE XX.
Length center to center of pinholes, 276″.07.
Gauged length along center line of web plate, 150″.
Test No. 4,217. Sectional Area, 13.16 square inches.

Applied Loads.		In gauged length.		Deflections at middle ″		E.	Increment of Comp. in ″.	Remarks.
Total lbs.	Lbs. per Sq. ″	Compression in ″.	Set in ″.	Horizontal.	Vertical.			
15,000	1,140	0	......	0	0			
20,000	1,520	.0014	......	0	0	162.860.000	.0014	Initial load.
40,000	3,040	.0095	......	0	0	48.040.000	.0081	
60,000	4,560	.0180	......	0	0	38.000.000	.0085	
80,000	6,080	.0263	......	0	0	34.677.000	.0083	
100,000	7,600	.0345	.0005	0	0	33.044.000	.0082	
110,000	8,360	.0389	......	0	0	32.240.000	.0044	
120,000	9,120	.0427	......	0	0	32.040.000	.0038	
130,000	9,880	.0469	......	.01	0	31.600.000	.0042	
140,000	10,640	.0511	......	.01	0	31.233.000	.0042	
150,000	11,400	.0554	......	.02	0	30.867.000	.0043	
160,000	12,160	.0596	......	.02	0	30.605.000	.0042	
170,000	12,920	.0640	......	.02	.02	30.281.000	.0054	
180,000	13,680	.0684	......	.02	.02	30.001.000	.0044	
190,000	14,440	.0726	......	.03	.02	29.834.000	.0042	
200,000	15,200	.0770	.0016	.03	.02	29.612.000	.0044	
			Set →	0	.02	....	....	Permanent movement of eyebar ends, A=.02″, B=.00½″.
210,000	15,960	.0812	......	.04	.03	29.484.000	.0042	
220,000	16,720	.0855	......	.04	.03	29.337.000	.0043	
230,000	17,480	.0898	......	.05	.04	29.200.000	.0043	
240,000	18,240	.0941	......	.05	.04	29.077.000	.0043	
250,000	19,000	.0984	......	.05	.04	28.962.000	.0043	Movement of eyebar ends under load, A=.02″, B=.00⅛″.
260,000	19,760	.1025	......	.05	.04	28.929.000	.0041	
270,000	20,520	.1068	......	.06	.04	28.822.000	.0043	
280,000	21,280	.1109	......	.06	.04	28.783.000	.0041	
290,000	22,040	.1153	......	.06	.04	28.674.000	.0044	
300,000	22,800	.1195	.0024	.06	.05	28.620.000	.0042	
			Set →	.02	.03			
310,000	23,560	.1235	......	.06	.05	28.618.000	.0040	
320,000	24,320	.1279	......	.07	.05	28.522.000	.0044	
330,000	25,080	.1323	......	.07	.05	28.436.000	.0044	
340,000	25,840	.1365	......	.08	.06	28.398.000	.0042	
350,000	26,600	.1412	......	.09	.06	28.258.000	.0047	Snapping sound.
360,000	27,360	.1456	......	.09	.06	28.187.000	.0044	
370,000	28,120	.1503	......	.10	.06	28.065.000	.0047	
380,000	28,800	.1549	......	.11	.06	27.890.000	.0046	Under load, A=.03″, B=.00⅛″.
390,000	29,640	.1600	......	.12	.06	27.787.000	.0051	
400,000	30,400	.1646	.0044	.13	.07	27.702.000	.0046	
			Set →	.04	.06	....	....	Permanent movement of eyebar ends, A=.02″, B=.00⅛″.
410,000	31,150	.1702	......	.14	.09	27.453.000	.0056	
420,000	31,910	.1748	......	.15	.09	27.383.000	.0046	
430,000	32,670	.1749	......	.16	.10	28.019.000	.0001	
440,000	33,430	.1854	......	.18	.10	27.048.000	.0105	
450,000	34,190	.1920	......	.20	.10	26.712.000	.0066	Under load, A=.06″, B=.00½″.
460,000	34,950	.1980	......	.23	.11	26.477.000	.0060	
470,000	35,710	.2045	......	.25	.12	26.192.000	.0065	
480,000	36,470	.2120	......	.30	.13	25.805.000	.0075	
490,000	37,230	.2205	.0180	.35	.16	25.326.000	.0085	
			Set →	.15	.11	....	....	Permanent movement of eyebar ends, A=.04″, B=.00½″.
500,000	37,990	....	......	.43	.17			
505,000	38.370	....	......	.50	.20			
510,000	38,750	....	......	.57	.23			
515,000	39,130	....	......	.65	.24	....	....	Ultimate strength.
513,000	....	....	......	.70	.26			
515,000	....	....	......	.83	.32			
......	....	....	......	1.06	.33			
500,000	....	....	......	1.58	.37			
440,000	....	....	......	2.50				

Post failed by buckling the eyebar sections at end A opposite the outside ends of the side plates

POST MADE FROM COMPRESSION STEEL—WEIGHT, 1,803 LBS

PIN IN VERTICAL POSITION.—PLATE XX.

Length center of pinhole to outside, 286″.57.
Gauged length along center line of upper web plate, 150.″
Test, No. 4,218. Sectional area, 12.95 square inches.

Applied Loads.		In gauged length.		Deflections at middle		E.	Increment of Comp.	Remarks.
Total lbs.	Lbs. per sq. ″.	Compression in ″.	Set in ″.	Horizontal.	Vertical.			
15,000	....	0	0	0	0	....	....	Initial load.
20,000	1.540	.0019	......	0	0	121.579.000	......	
40,000	3.090	.0101	......	0	0	45.891.000	.0082	
60,000	4.630	.0182	......	0	0	38.159.000	.0081	
80,000	6.180	.0263	......	0	0	35.247.000	.0081	
100,000	7.720	.0343	.0003	0	0	33.761.000	.0080	
110,000	8.490	.0378	......	0	.02	33.691.000	.0035	
120,000	9.270	.0419	......	0	.02	33.186.000	.0041	
130,000	10.040	.0458	......	0	.03	32.882.000	.0039	
140,000	10.810	.0500	......	.01	.03	32.4[illegible]0.000	.0042	
150,000	11.580	.0540	......	.01	.04	32.167.000	.0040	
160,000	12.360	.0582	......	.01	.04	31.856.000	.0042	
170,000	13.130	.0623	......	.01	.04	31.613.000	.0041	
180,000	13.900	.0664	......	.01	.04	31.400.000	.0041	Deflection sets.
190,000	14.670	.0705	......	.01	.05	31.213.000	.0041	Horizontal Vertical.
200,000	15.450	.0746	.0001	.01	.05	31.066.000	.0041	0 0
210,000	16.220	.0785	......	.01	.06	30.994.000	.0041	
220,000	16.990	.0827	......	.01	.06	30.817.000	.0042	
230,000	17.760	.0868	......	.01	.06	30.691.000	.0041	
240.000	18.530	.0910	......	.01	.06	30.544.000	.0042	
250,000	19.310	.0951	......	.01	.06	30.458.000	.0041	
260,000	20.080	.0995	......	.01	.06	30.271.000	.0044	
270,000	20.850	.1038	......	.01	.06	30.130.000	.0043	
280,000	21.620	.1080	......	.01	.06	30.028.000	.0042	
290,000	22.390	.1124	......	.01	.06	29.880.000	.0044	
300.000	23.170	.1167	.0001	.01	.06	29.781.000	.0043	0 .04″.
310.000	23.940	.1212	.....	.01	.06	29.629.000	.0045	
320.000	24.710	.1266	......	.01	.06	29.277.000	.0054	
330.000	25.480	.1297	......	.01	.06	29.468.000	.0031	
340.000	26.260	.1345	......	.01	.06	29.286.000	.0048	
350.000	27.030	.1390	......	0	.04	29.169.000	.0045	
360.000	27.800	.1434	......	0	.04	29.079.000	.0044	
370.000	28.570	.1479	......	0	.03	28.976.000	.0045	
380.000	29.340	.1529	......	0	.03	28.783.000	.0050	
390.000	30.120	.1575	... ..	0	.03	26.686.000	.0046	
400.000	30.890	.1622	.0035	0	.03	28.567.000	.0047	0 .03″.
410.000	31.660	.1674	......	0	.05	28.370.000	.0052	
420.000	32.430	.1724	......	0	.05	28.216.000	.0050	
430.000	33.210	.1768	......	0	.05	28.176.000	.0044	
440.000	33.980	.1825	......	0	.05	27.929.000	.0057	
450.000	34.750	.1871	......	0	.06	27.860.000	.0046	
460.000	35.520	.1929	......	0	.06	27.621.000	.0058	
470.000	36.290	.1985	......	0	.04	27.423.000	.0056	
480.000	37.070	.2034	......	0	.04	27.338.000	.0049	
490.000	37.840	.2093	......	0	.03	27.119.000	.0059	
500.000	38.610	.2149	.0138	0	.08	26.950.000	.0056	0 .01″.
510.000	39.380	.2211	......	.01	.03	26.716.000	.0062	
520.000	40.150	.2278	......	.01	.02	26.438.000	.0067	
530.000	40.930	.2333	......	.01	.01	26.316.000	.0055	
540.000	41.700	.2390	.....	.01	.01	26.172.000	.0057	
550.000	42.470	.2465	......	.01	.01	25.843.000	.0075	Snapping sounds.
560.000	43.240	.2540	......	-.02	0	25.536.000	.0075	
570.000	44.020	.2690	.....	-.05	-.01	24.546.000	.0150	
580.000	44.790	.2787	......	-.10	-.02	24.107.000	.0097	
590.000	45.560	.2915	......	-.21	-.03	23.444.000	.0128	
597.000	46.147	....	......	-.40	0	....	....	Ultimate strength.
560.000	....	....	......	-.85	0			
330.000	....	....	......	-2.30	...	....	....	Sudden deflection

Post failed by deflection in a plane perpendicular to the plane of the axis of the pin.

The deflection increased gradually until the horizontal movement reached -.85″ when the post rapidly deflected to 2.30″; in the meantime the web plates and angles buckled on the concave side at a distance of 8 feet from the pin end.

Pinholes elongated .02″+

Correct, J. E. HOWARD.

F. H. PARKER,
Major Ordinance Dept., U. S. A.,
Commanding.

SPECIMEN TESTS OF STEEL IN TENSION POST.

Date, 1885.	Heat No.	Specimen cut from.	Area of Specimen.	Elastic Limit: Pounds per Sq. Inch.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8".	Reduction of Area, %.	Carbon.	Manganese.	Modulus of Elasticity.	Remarks.
12/21	6653	2½×2½×$^5/_{16}$ angle	.2943	45.300	78.320	15.8	51.2	....	....	28.814.000	Specimen $^5/_{16}$ thick. Fracture irregular. Silky.
"	"	6×1⅛ bar	.4465	35.833	71.150	25.0	38.8	....	....	27.715.000	Specimen from crop end turned up ¾" round.
	"	"	.4465	38.475	78.160	23.3	39.8	..	....	29.643.000	Specimen from bar, turned up ¾" round. Fracture—silky edges—pitted center.
9/28	"	¾ round. Ingot test	.4336	49.360	72.420	23.8	44.2	...	...	....	Very irregular—silky.
"	"	"	.4336	48.430	72.420	24.9	51.1	.18	?	29.290.000	

COMPRESSION POST.

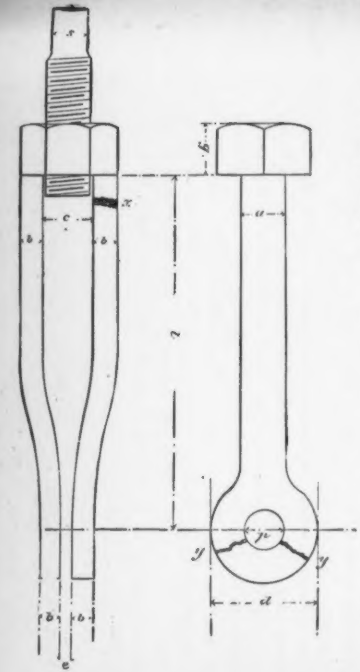
12/21	6738	2½×2½×$^5/_{16}$ angle	.2895	46.290	73.920	23.3	57.4	. ..	....	30.285.000	Fine silky cup.
8/19	"	¾ round. Ingot test	.4347	51.760	83.510	18.4	30.5	.34	.68	....	Silky at 45°—crystal spot.
"	"	"	.4394	51.210	83.730	16.6	26.8	....	....	29.840.000	
1886 1/28	4341	11×$^5/_{16}$ pl.	.614	59.900	81.600 +	6.0	6.2	...	....	....	Machine could not break.
1885 2/?	"	¾ round, Ingot test	......	48.206	84.035	23.2	40.4	.31	.78	... .	Tested at Fairbanks, Phila.
"	"	"	......	......	85.650	23.3	37.9	....	....	....	Tested at Carnegie's, Pgh.
2/12	"	"	......	52.000	86.740	21.9	40.3	....	....	... .	Tested at Steelton.

The above tests on specimens of steel used in the two posts appear somewhat anomalous, but this may be due to the cases where crop ends only were available for specimens, and to the sometimes imperfect action of the grips of testing machines on very thin specimens. The record is offered, however, as received from inspectors who made all the tests independently of each other.

The following tests were made to ascertain if crucible steel castings had progressed to the point of excellence in small pieces to permit their substitution for difficult and costly forgings.

It was suggested to the writer to use them for clevises, and a set of sample clevises were made by the Pittsburgh Steel Casting Co. The results were not encouraging, as shown in table of tests, but it is to be hoped that in the near future, honeycombing may be eliminated by the use of some device to produce artificial pressure enough to force out the imprisoned gases, and small steel castings be produced as perfect as the many large ones daily turned out.

Iron clevises were finally used, tests having been made on samples of the sizes required in the structure, with results as shown.



CAST STEEL CLEVISES MADE BY PITTSBURGH STEEL CASTING CO.

Note.—Tests made at Athens on old screw action machine, capacity 150,000 lbs., known to be somewhat inaccurate in readings being out of repair.

No. of Test.	Size of Rod.	Diam. of Upset.	Dimensions of Clevises, Inches.						Original Sectional Areas in Square Inches.				Breaking Strength, per Square Inch, developed.			Point of Fracture.	Remarks.
			a	b	d	p	l	e	Rod.	Upset.	Eye.	2 Wings.	In Rod.	In Clevis Wings.	At Fracture.		
1	1⅜″ sq	1 13/16	2	¾	5	2	8	1⅝	1.89	2.58	4.5	3.0	10.600	6.720	6.720	At "x"	One clevis broke short off on both wings at "x"—no flaws visible before test. Fracture showed honey-combed structure for about one-half area of cross section.
2	1⅜″ sq	1 13/16	2	¾	5⅜	2⅛	6	2⅝	1.89	2.58	4.3	3.0	45.900	28.900	20.150	At "yy"	One clevis broke across one eye at "y y"—no flaws visible before test. Sections at fracture honey-combed—one for one-half area—other for one-fourth.
3	1⅝″ sq	2 1/16	2½	¾	5⅞	2¼	8¼	1⅝	2.64	3.34	5.45	3.75	46.200	32.500	32.500	At "x"	Double fracture in one clevis wing at "x"—no flaws visible before test. Sections at fracture honey-combed—one for one-half area—other for one-fifth.
4	1⅛″ sq	1 7/16	1¾	¾	4½	2	....	....	1.27	1.62	3.75	2.63	46.900	22.660	36.660	Upset	Broke in upset on rod taken from old bridge. Not made at Athens shop.
5	1⅛″ sq	1 7/16	1¾	¾	4½	2	....	....	1.27	1.62	3.75	2.63	55.200	26.600	55.200	Rod.	

WROUGHT IRON CLEVISES MADE BY COFRODE & SAYLOR.

No. of Test.	Size of Rod.	Diam. of Upset.	a	b	d	p	l	e	Rod.	Upset.	Eye.	2 Wings.	In Rod.	In Clevis Wings.	At Fracture.	Point of Fracture.	Remarks.
6	1⅛″ sq	1 7/16	2	¾	....	8	....	....	1.27	....	....	3.0	51.400	21.700	51.400	Rod	Rod had clevises at both ends.
7	1⅝″ sq	2 1/16	2⅜	¾	....	....	....	....	2.64	....	....	3.56	45.800	34.900	45.800	Rod	Rod had clevis at one end and loop at other—loop 1¾×1 3/16 on 2 7/16″ pin. Reduction of area in rod at fracture, 48%.
9	1⅜″ sq	1 13/16	2	¾	5	2	....	....	1.89	....	....	3.	44.800	28.200	44.800	Rod	Rod had clevis at one end and loop at other—loop 1⅜×1⅛ on 2 7/16″ pin. Reduction of area, 46%.

SPECIMEN TESTS OF STEEL PINS ("TENSION" STEEL).

Tests marked Skin were cut as near outside as possible.
Tests marked Center were cut at center.
All specimens turned up round.
9¼ and 7½" pins forged from 11 inch square and 10 inch square blooms.
All other pins rolled in gothic rolls from 7"×8" blooms.
Those marked * have ingot test shown elsewhere with tension plates.
Steel made by Penna. Steel Co. and pins made at Carnegie's.

Date, 1885.	Heat No.	Size of Pin.	Area of Specimen.	Limit of Elasticity per Sq. Inch.	Ultimate Strength per Sq. Inch.	Elongation in 8"%.	Reduction %.	Where cut from.	Carbon.	Manganese.	Remarks on Fracture.
11/27	4732*	2⅜" round	.5026	39.940	68.500	25.0	44.7	Skin	......	.....	Fine silky.
"	4778	2⅞" round	.5064	41.170	71.100	24.0	46.9	"	......	......	Part "
8/10	"	Ingot	.4336	47.770	78.220	22.8	40.1	....	.22	.58	
"	"	"	.4336	49.020	78.190	22.5	39.1				
11/27	4776*	3⅜" round	.5026	38.655	69.970	17.6	48.7	Skin	......	.. ...	Fine silky.
"	4780*	5⅝" round	.5052	38.756	69.730	24.5	45.3	Skin	Same	Pin	Irregular—part silky.
"	"	"	.5052	41.680	65.710	20.0	30.0	Center			Square with granular center.
"	4868*	"	.5115	38.840	69.795	23.0	46.4	Skin	Same	Pin	Shallow—part silky.
"	"	"	.5140	41.090	65.480	18.8	30.8	Center			Jagged—part silky—center granular.
"	"	4⅞" round	.5166	38.595	70.130	23.1	52.3	Skin	... ..	......	Fine silky.
11/28	4776*	6⅜" round	.5001	39.730	69.880	22.0	52.5	Skin	Same	Pin	" "
"	"	"	.5039	41.095	66.650	20.0	24.7	Center			Square—granular throughout.
"	4772*	6⅝" round	.5166	38.760	70.480	26.3	50.6	Skin	Same	Pin	Fine silky.
"	"	"	.5140	42.850	67.490	18.0	29.3	Center			Irregular — center granular.
11/30	4649*	6⅞" round	.5089	39.790	69.830	26.9	53.7	Skin	Same	Pin	Shallow—part silky.
"	"	"	.5039	41.035	67.490	16.3	24.7	Center			Irregular — center granular.
"	4644	6⅜" round	.5178	38.760	72.540	25.0	45.4	Skin	Same	Pin	Fine silky.
"	"	"	.5115	41.080	67.490	19.5	43.4	Center			Shallow — center pitted and granular.
6/5	"	Ingot	.4525	48 190	74.920	23.5	40.5	....	.20	.76	Fine silky.
"	"	"	.4525	49.500	75.280	25.5	40.5	....	......	......	At 45° silky.
11/28	4774*	7½" round	.4976	41.920	72.370	30.3	53.6	Skin	Same	Pin	Fine silky.
"	"	"	.5064	39.040	67.510	18.1	30.4	Center			Edges silky—center granular.
"	4740	9¼" round	.5039	40.840	71.980	26.8	54.5	Skin	Same	Pin	Fine silky.
"	"	"	.5026	38.860	65.470	17.5	29.8	Center			Edges silky—center coarsely granular.
8/6	"	Ingot	.4371	47.200	70.320	24.5	46.0	....	.20	.58	
"	"	"	.4371	47.540	70.230	24.3	44.1				

SHEARING STEEL PLATES.

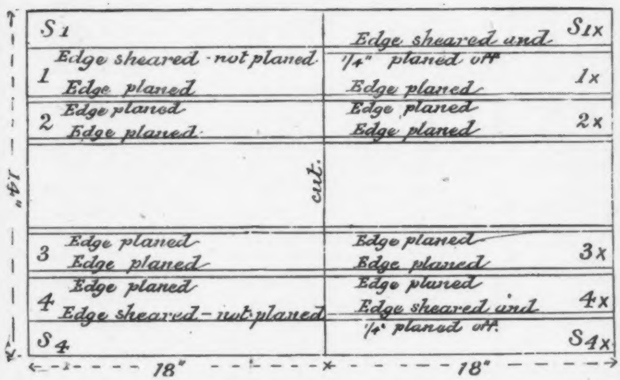
The following tests were made to determine, if possible, the damage done to steel plates by shearing the edges, and to ascertain whether planing off ¼" from the sheared edges removes the injury to the plate.

The specimens were prepared as indicated in sketch and table, straightened without hammering and broken in 50,000 lb. Olsen lever machine at Athens.

" It was not possible to note the depth to which the shearing affected the material, by inspection of the edges before breaking, nor by any difference in the fracture after pulling; the fracture was in every case but one, entirely silky. One specimen mainly crystalline, was silky on the sheared side as noted in the table."

Steel made at Penna. Steel Co.'s mills and rolled at Elmira Rolling Mill. Slabs 14¼"x1¼" and 1½". Steel same grade as used in structure, made under same specification.

Sketch.



Mark.	Treatment of Specimen.	Specimen cut from.	Area of Specimen.	Limit of Elasticity per sq." lbs.	Ultimate Strength: Pounds per Sq. Inch.	Elongation, % in 8 Inches.	Reduction of Area, %.	Carbon.	Manganese.	Remarks on Fracture.
1	1 edge sheared, other planed.	14″×5/16″ Tension plate. Specimens, 1¼″×5/16″.	.3843	42.270	68.030	....	....	....	....	Not completely broken.
2	Both edges planed.		.3936	41.410	66.060	24.4	49.8	....	....	Silky. Broke in lamination.
3	Both edges planed.		.3924	41.890	67.670	25.7	54.4	....	....	Silky. Sheared at 45°. Broke 4″ from grip. Broke 2″ from end.
4	1 edge sheared, other planed.		.3862	43.240	67.580	16.0	29.4	....	....	Silky. Broke on sheared edge, first starting to tear in many places.
1x	1 edge sheared. then planed ¼″, other edge planed.		.3860	41.210	68.000	24.0	49.6	....	....	Silky at 45°.
2x	Both edges planed.	....	.3948	41.600	68.000	23.2	49.8	....	....	A little crooked—laminated.
3x	Both edges planed.	....	.3924	41.910	68.430	23.5	49.1	....	....	" " " silky irregular.
4x	Same as 1x.	....	.3875	41.290	68.130	23.5	53.1	....	....	" " " " cup-fine.
4561	Ingot test.	¾″ round	......	51.670	74.570	25.9	55.6	.22	.65	Silky—part crystal. Break started on sheared edge, broke with more snap than 5/16″ pieces.
1	Treatment same as in other specimens of same marks.	14″×7/16″ Tension plate. Specimens, 1″×7/16″.	.4383	47.450	74.370	19.1	36.2	....	....	Silky—concave—10% crystal, broke 3″ from grip.
2			.4348	43.240	72.920	23.1	52.1	....	....	Ditto.
3			.4328	42.060	72.650	21.6	49.1	....	....	Irregular silky—part fine crystal—break started in many points on sheared edge, broke 2″ from grip.
4			.4310	41.070	74.230	16.2	31.0	....	....	Silky cup—part very fine crystal.
1x			.4288	43.610	74.630	23.1	50.3	....	....	Irregular cup, dull center, broke 3″ from grip.
2x	....		.4308	44.330	73.800	23.1	46.8	....	....	
3x	....		.4308	44.800	75.200	20.5	50.2	....	....	Ditto.
4x	....		.4308	43.640	75.430	22.2	51.9	....	...	Irregular cup, fine silky, broke 3″ from end—small lamination in center.
S_1	1 edge sheared, then planed ⅜″, other edge planed.	....	.4350	45.370	75.270	23.0	39.6	....	....	Very irregular—fine silky.
S_4	Ditto.	....	.4300	46.290	75.800	19.6	51.2	....	....	Irregular—part fine crystal.
4976	Ingot test	¾″ round	......	50.770	76.650	22.5	52.0	.24	.77	

1	Treatment same as in other specimens with same marks.	14″×⅝″ Tension plate. Specimens, ¾″×⅝″.	.4697	53.000 (?)	74.720	14.1	28.5	....	...	At 45° silky—broke from sheared edge—bent in testing.
2			.4637	39.90[illegible]	73.3[illegible]0	25.6	57.3	....	...	Half cup—silky—regular.
3			.4693	41.330	73.550	16.5	50.3	....	....	" " "
4			.4812	47.290	75.330	12.5	21.9	....	....	Bent in testing—broke 3″ from end with oblique sheared. Silky.
1x			.4656	41.230	72.600	22.7	44.6	....	....	Irregular cup—silky—trace very fine crystal.
2x			.4681	41.600	70.900	26.0	55.6	....	....	Cup silky.
3x			.4696	42.500	71.700	20.8	50.7	....	....	Irregular silky.
4x			.4666	42.540	73.190	20.4	54.1	....	...	" "
4796	Ingot test.	¾ round	......	50.770	76.650	22.5	52.0	.24	.77	
1	Treatment same as in other specimens with same marks.	14″×5/16″ Compression plate. Specimens, 1¼″×5/16″.	.3968	48.760	75.100	15.5	23.8	....	....	Very rough sheared. Silky, irregular bent in testing. Break started on sheared edge.
2			.3968	47.370	75.100	23.4	42.9	....	....	At 45° silky.
3			.3906	48.130	74.900	25.9	44.2	....	....	A little crooked—irregular, very silky.
4			.3869	49.740	75.220	13.8	20.4	....	....	Very rough sheared. Broke suddenly at 45°—silky. Started breaking at sheared edge.
1x			.3906	50.700	75.660	22.5	44.6	....	....	Started on planed edge at 45° silky.
2x			.3918	46.960	74.780	23.0	46.1	....	....	Piece a little crooked. Part cup silky.
3x			.3869	48.070	75.230	22.9	44.8	....	....	Piece quite crooked. At 45° silky.
4x			.3869	48.900	74.630	20.8	40.5	....	....	Piece a little crooked. Very irregular silky.
4340	Ingot test.		......	52.340	81.260	22.3	41.3	.27	.85	
1	Treatment same as in other specimens with same marks.	14″×7/16″ Compression plate. Specimens, 1″×7/16″.	.4466	49.490	72.820	11.0	19.4	....	....	Sheared very rough—intermediate seam—crooked—started in dent on sheared edge. Silky at 45°.
2			.4365	48.570	74.470	21.9	45.1	....	....	Silky at 45°.
3			.4345	48.790	73.880	23.3	50.0	....	....	" " "
4			.4383	51.220	74.600	14.2	23.9	....	....	Broke in hollow spot on sheared edge—oblique fracture silky.
1x			.4333	48.250	74.460	25.2	44.9	....	....	Irregular silky—broke in punch mark.
2x			.4354	47.320	73.830	28.5	44.9	....	...	Part cup—fine silky.
3x			.4369	48.060	74.150	24.6	42.9	....	....	Broke 1″ from grip, irregular silky.
4x			.4358	47.060	74.580	24.6	48.8	....	....	At 45° silky.
S_2	One edge sheared and then planed ⅛″—other edge planed.		.4330	52.510	78.080	20.5	49.7	....	....	Irregular cup silky. Began tearing on sheared edge.
S_4 x	Ditto.		.4330	52.050	78.540	23.5	47.8	....	....	Irregular cup silky, bent in tearing.
4340	Ingot test.	¾ round	......	52.340	81.260	22.3	41.3	.27	.85	
1	Treatment same as in other specimens with same marks.	14″×⅝″ Compression plate. Specimens, ¾″×⅝″.	.4781	60.780 (?)	74.200	21.2	18.1	....	....	Rough piece with seams ¾ crystalline towards planed side.
2			.4636	39.710	74.120	24.2	48.6	....	....	Partial cup—part crystalline
3			.4649	41.300	74.320	24.3	49.6	....	....	Flat cup silky.
4			.4634	51.790	74.450	20.6	11.6			Sheared rough with seams broke in seam. Elastic Limit taken with dividers.
1x			.4584	40.790	74.160	24.2	50.2	....	....	Silky—regular.
2x			.4607	41.040	73.150	23.5	36.0	....	....	" irregular—traces of crystal.
3x			.4642	41.170	73.600	25.5	52.6	....	....	Cup silky.
4x			.4601	41.080	74.450	23.7	44.4	....	....	Half cup silky—broke in punch mark.
340	Ingot test.	¾ round	.....	52.340	81.260	22.3	41.3	.27	.85	

HAMMERING STEEL PLATES.

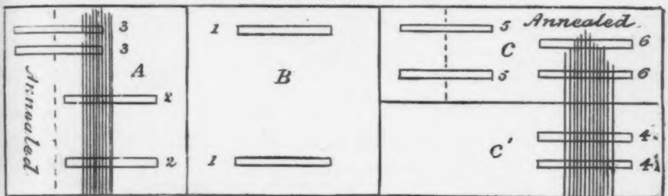


Plate cut up into parts A, B, C and C'.

A. Hammered while hot. (Heated between dull red plates.) After hammering and cooling, part up to dotted line was reheated and cooled in ashes between two hot plates.

B. Normal plate, not hammered.

C. Hammered while cold. Part up to dotted line afterward annealed as in case of A.

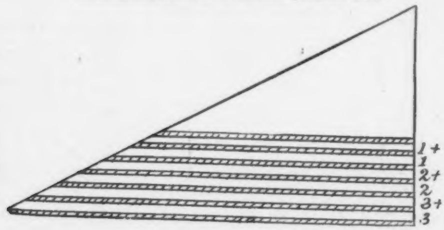
C'. Hammered cold. Not annealed.

Plate originally buckled as indicated in shaded parts. Hammered only enough to straighten out.

1885	Test.	Specimen cut from.	Area of Specimen: Sq. Inches.	Elastic Limit per Sq. Inch: Pounds.	Ultimate Strength per Sq. Inch: lbs.	Elongation in 8", %.	Reduction of Area, %.		Remarks on Fracture.
9/18	No. 1	24×3/8	.358	52.200	85.900	22.1	39.9		Slightly laminated.
"	" 1	"	"	56.700	86.300	22.9	47.7		"
"	" 2	"	.358	55.800	90.100	17.3	46.1		Part cup silky.
"	" 2	"	.357	55.200	90.300	17.5	36.4		" " "
"	" 3	"	.357	56.000	89.600	18.6	37.6	Broke near edge of annealed portion.	" " "
"	" 3	"	"	56.000	88.200	18.1	36.7	" "	" " "
"	" 4	"	.360	51.900	87.000	21.9	40.8		Slightly laminated.
"	" 4	"	.361	50.900	86.100	19.8	34.3		" "
"	" 5	"	.359	52.900	86.300	16.2	44.0		Part cup silky.
"	" 5	"	.363	55.100	88.100?	16.2	38.3		" "
"	" 6	"	.364	53.600	85.000	20.6	35.4		Slightly laminated.
"	" 6	"	.363	53.700	85.400	21.6	47.6		" "

Tested at Athens.

HAMMERING STEEL PLATES.



Test pieces Nos. 3 and 3+ taken off when plate was in normal condition. Plate then heated to cherry red and bent ½″ out of plane. Hammered plate till it was entirely covered with hammer marks. Test pieces Nos. 2 and 2+ then cut off. Plate then annealed by placing between two other plates, 1¼″ thick, heated to dull red. All covered with ashes and cinder and left over night to cool. Test pieces Nos. 1 and 1+ then cut off.

1885.	Mark.	Specimen cut from.	Area of Specimen: Sq. Inches.	Elastic Limit per Sq. Inch: Pounds.	Ultimate Strength per Sq. Inch: Pounds.	Elongation in 8″, %.	Reduction of Area, %.	Remarks on Fracture.
9/26	No. 3	30×⅝	.457	45.700	71.500	18.1	42.0	Broke at surface. Slag pit section measurement necessarily inaccurate.
"	" 3+	"	.433	48.000	72.100	18.1	38.0	Badly pitted on one side. Calipered as near an average as possible.
"	" 2	"	.389	37.600	70.700	22.5	53.7	Pitted surface planed of.
"	" 2+	"	.389	37.500	......	22.1	47.8	"
"	" 1	"	.398	36.100	66.800	20.3	49.8	"
"	" 1+	"	.389	35.500	65.900	19.6	46.0	"

Tested at Athens.

The foregoing tests were made at Athens and were occasioned by an accident. A long plate 26″x⅝″ had come in from mill with several buckled spots in it, and the men in the yard took it to the platen and hammered them out without the fact being noticed.

On observing the hammer marks on the plate afterwards, when being bolted up in its proper member, the writer had the member laid aside, hammering cold being distinctly specified against.

The urgent need of completion of the member in question, and impossibility of replacing the plate under three to four weeks, and thus delaying the erection of the bridge that long, made it a serious affair if the plate must be rejected.

To decide the matter, the tests recorded above were made and as a result the plate allowed to go into the member, which was a chord section strained in compression.

The writer desires at this time to acknowledge, with due appreciation, the hearty co-operation of the Union Bridge Co., in his endeavors to make such tests as were necessary to arrive at true conclusions in all cases of doubt, and trusts that the results have proved as satisfactory to them as to himself.

Also to record his satisfaction at the care and painstaking efforts of the several inspecting engineers engaged with him in the work to obtain proper material and workmanship, and in carrying on the special tests.

PLATE XIII.
TRANS, AM. SOC. CIV. ENG'RS.
VOL. XVII, NO. 365.
MOULTON ON
KENTUCKY AND INDIANA BRIDGE.

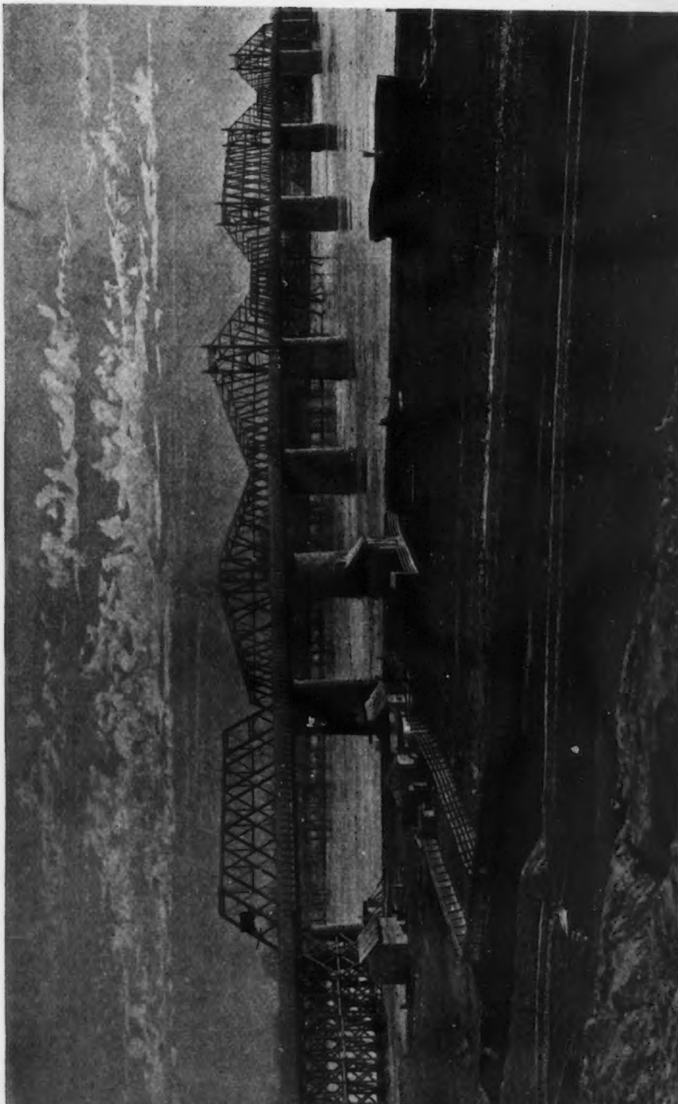
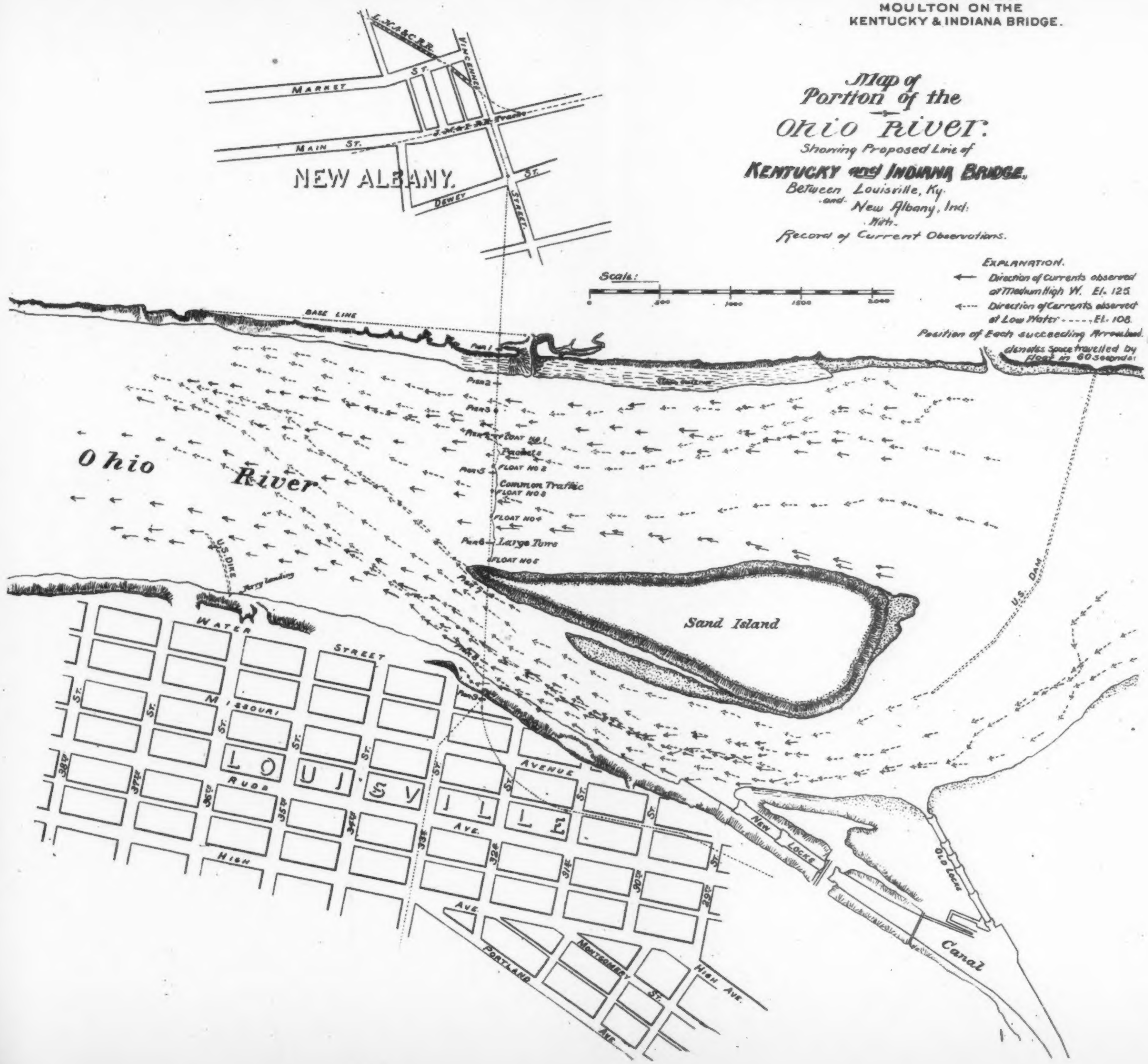
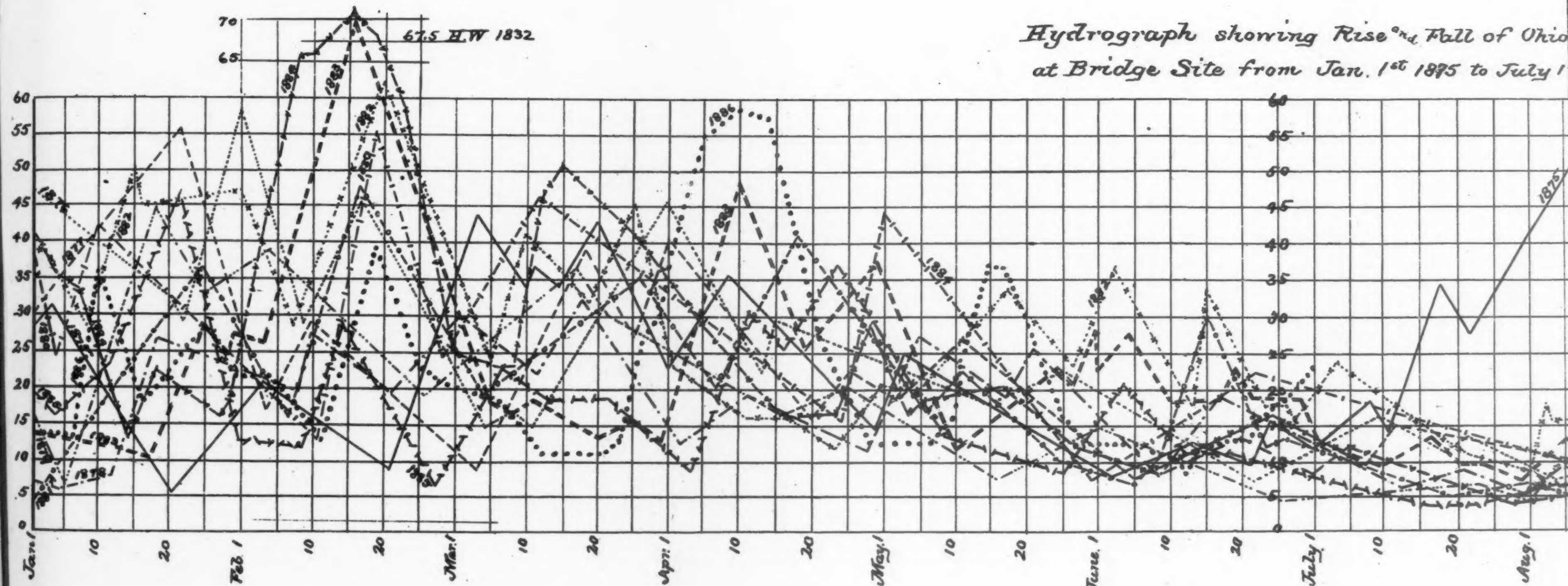


PLATE XIV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XVII Nº 365.
MOULTON ON THE
KENTUCKY & INDIANA BRIDGE.





Hydrograph showing Rise and Fall of Ohio
at Bridge Site from Jan. 1st 1875 to July 1
67.5 H.W 1832
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Jan. 1
10
20
Feb. 1
10
20
Mar. 1
10
20
Apr. 1
10
20
May 1
10
20
June 1
10
20
July 1
10
20
Aug. 1
1875
1886
1883
1884

PLATE XV
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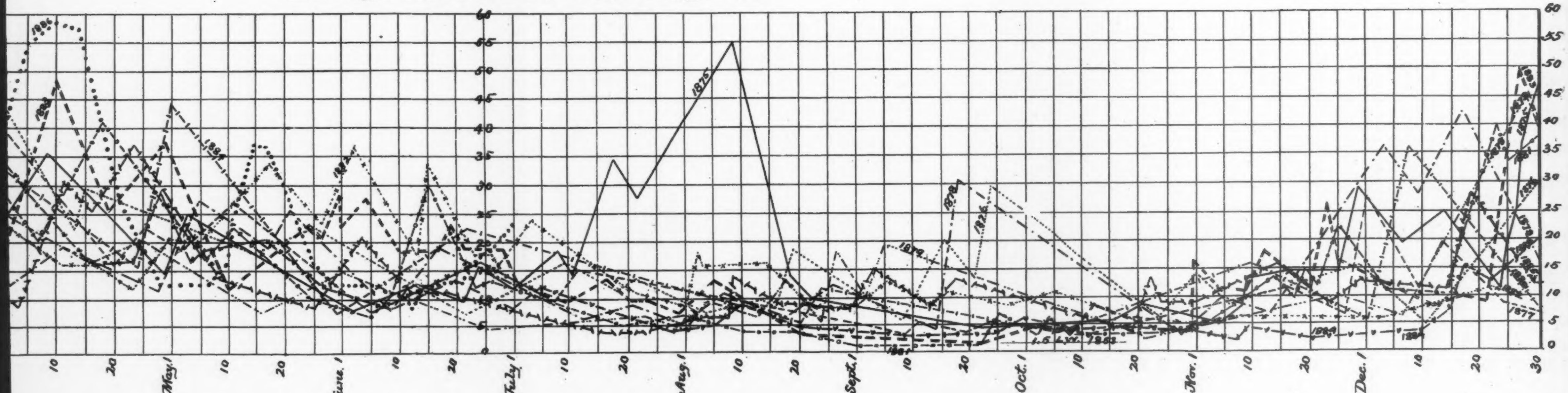
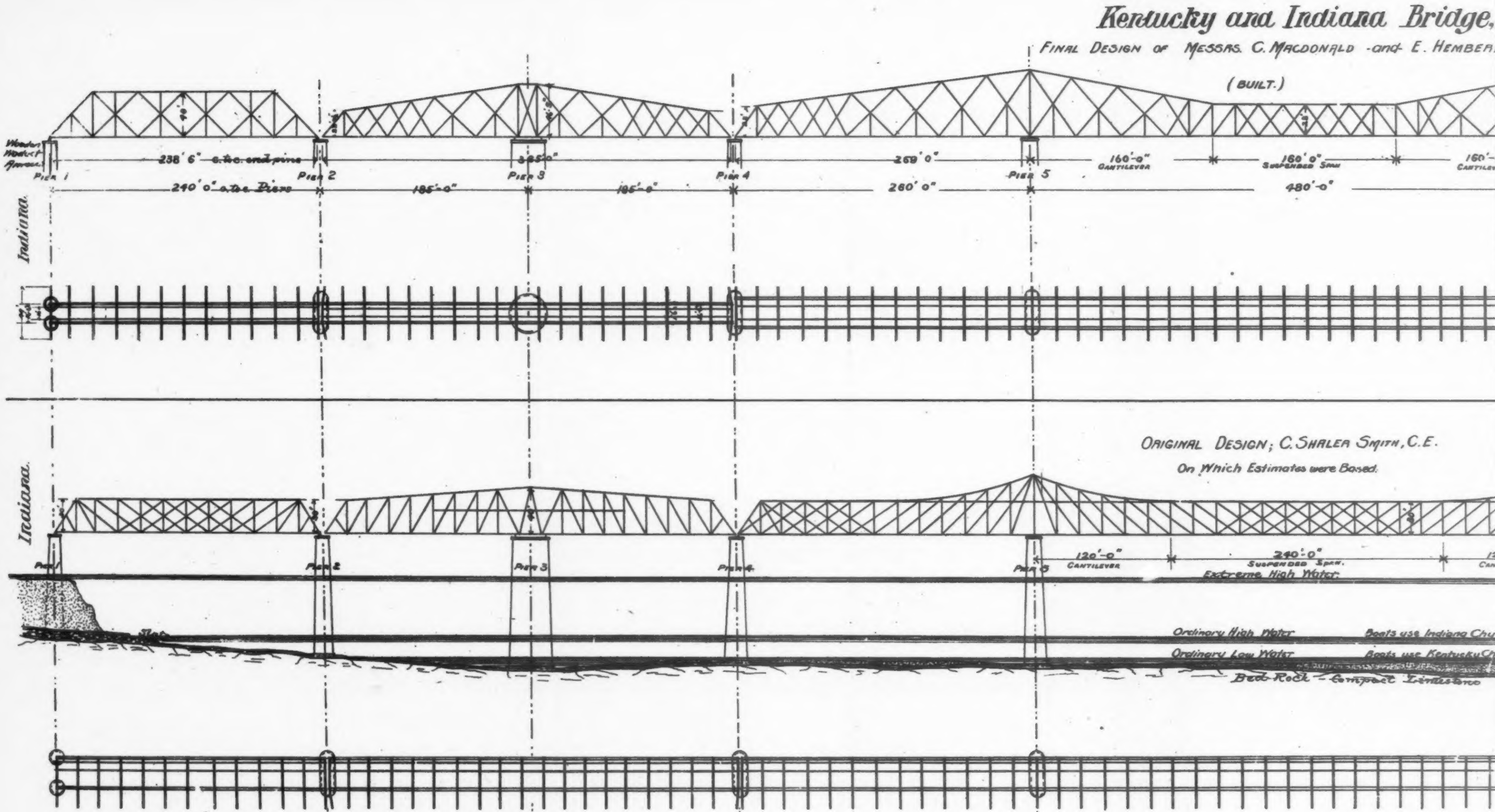
Hydrograph showing Rise and Fall of Ohio River
at Bridge Site from Jan. 1st 1875 to July 1st 1886.





Kentucky and Indiana Bridge,
Final Design of Messrs. C. Macdonald -and- E. Hemberl
(Built.)
Indiana.
Pier 1
Pier 2
Pier 3
Pier 4
Pier 5
238' 6" c. to c. end pins
265' 0"
259' 0"
160'-0" Cantilever
160' 0" Suspended Span
240' 0" c. to c. Piers
185'-0"
185'-0"
260' 0"
480'-0"
Original Design; C. Shaler Smith, C.E.
On Which Estimates were Based.
Indiana.
120'-0" Cantilever
240'-0" Suspended Span
Extreme High Water
Ordinary High Water
Boats use Indiana Chu
Ordinary Low Water
Boats use Kentucky Ch
Bed Rock - Compact Limestone

PLATE XVI
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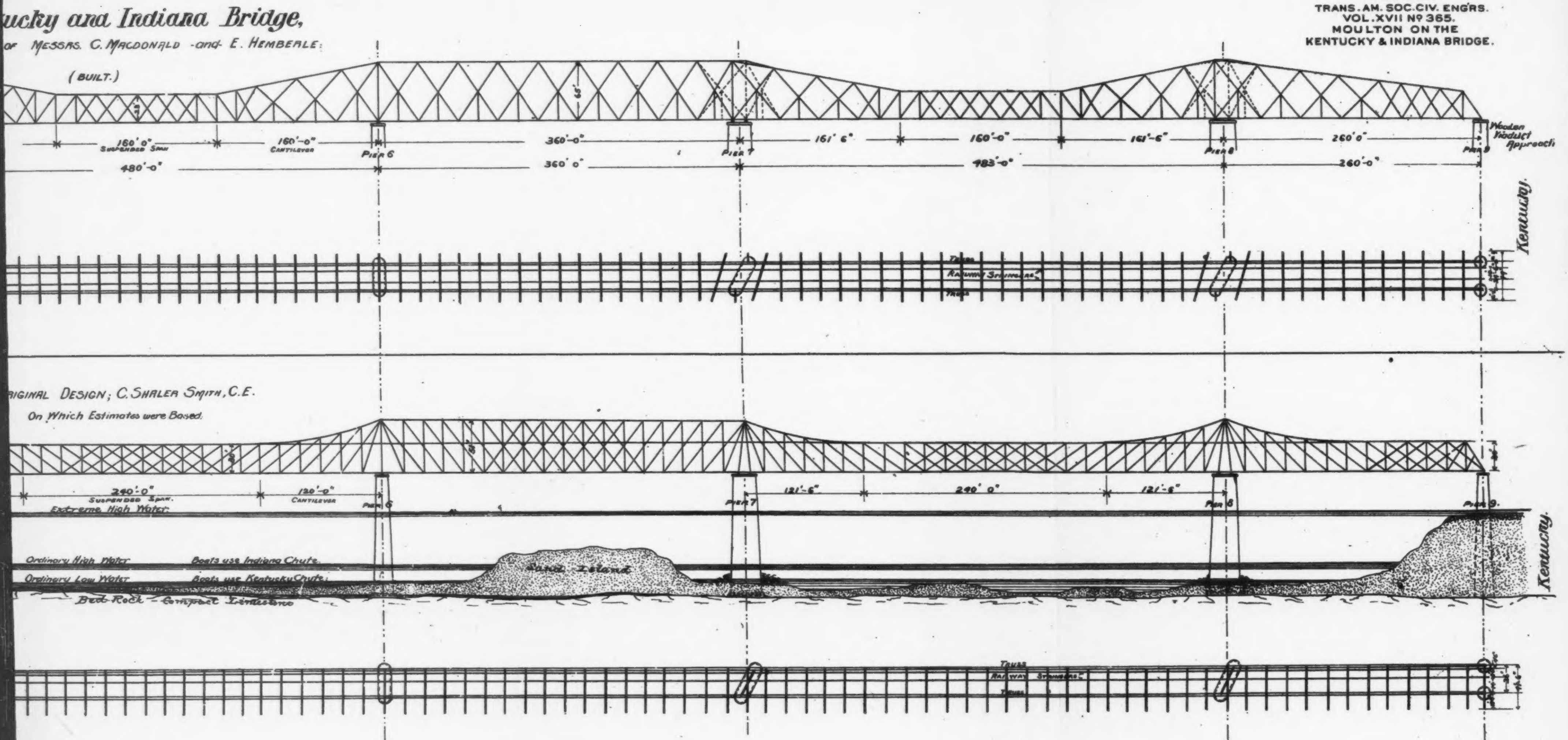

PLATE XVII
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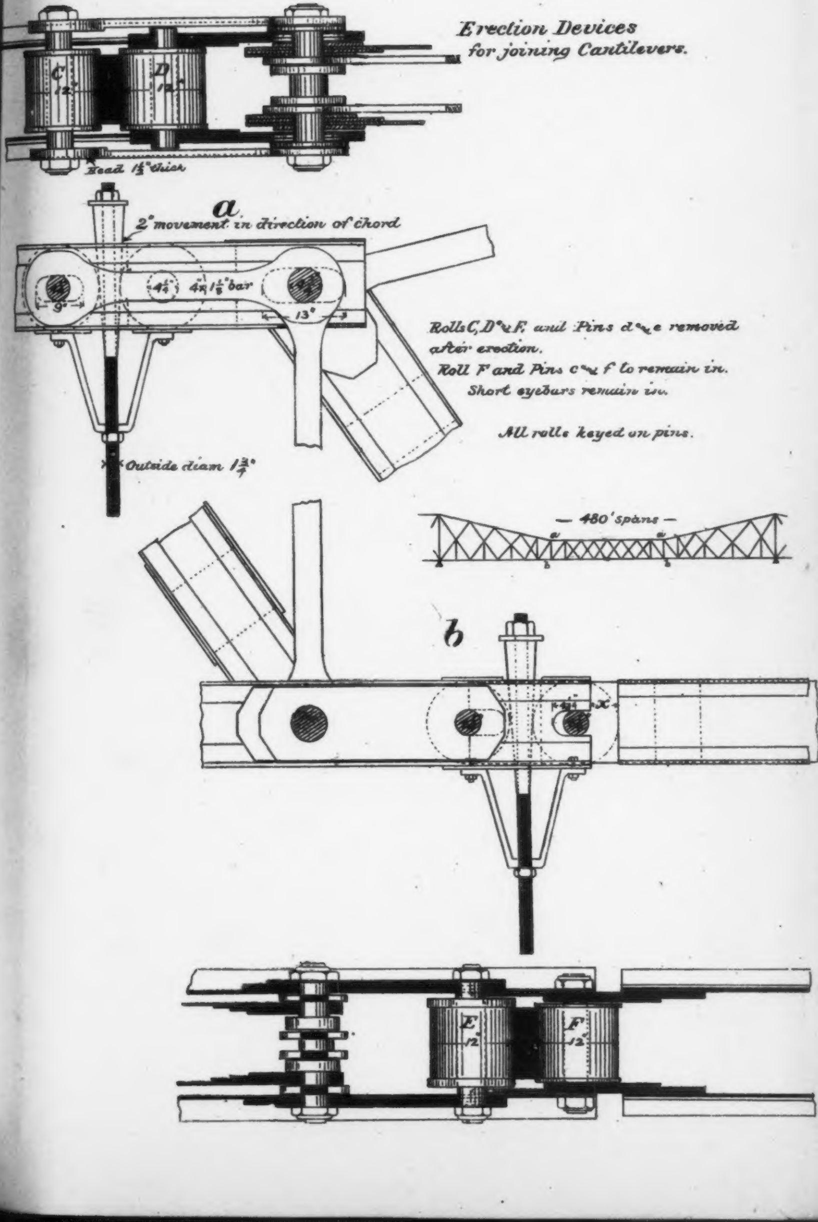
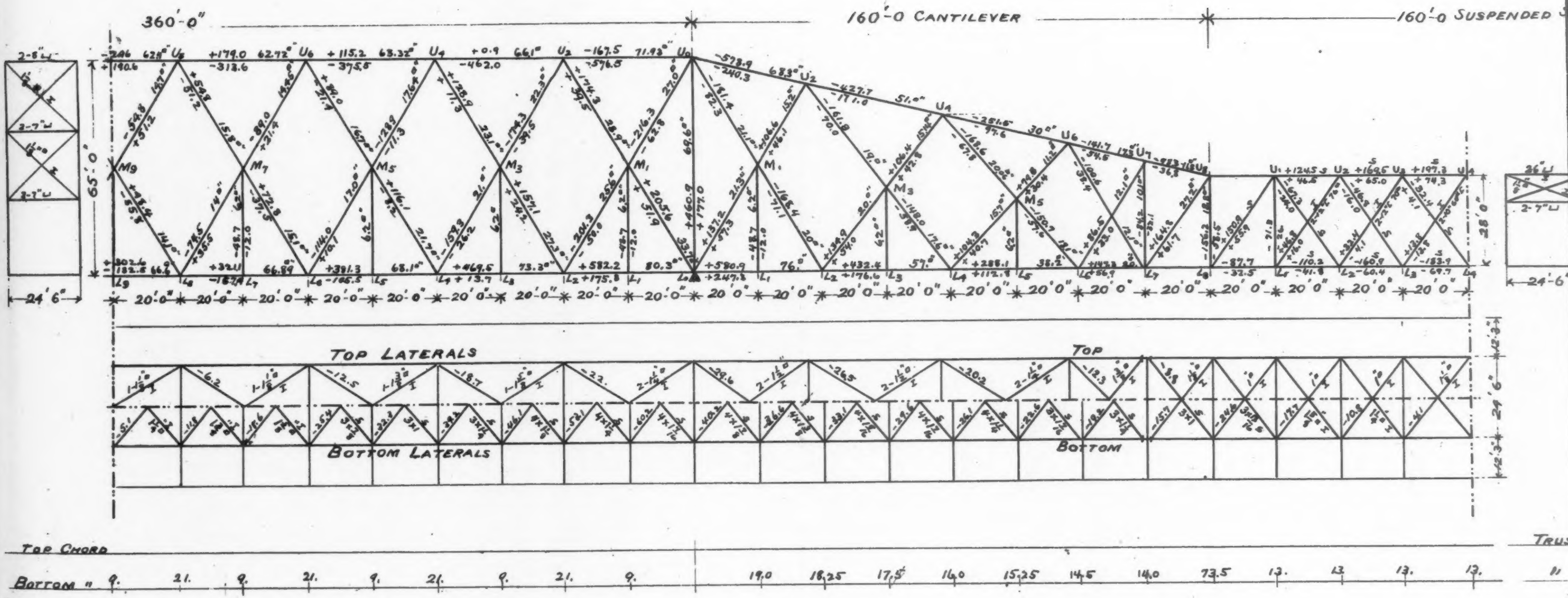
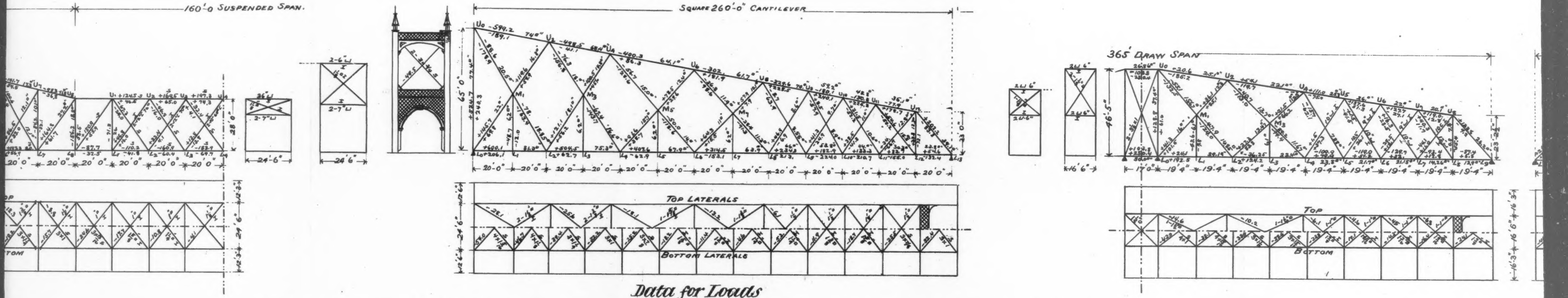


All loads and



Stress Diagram Kentucky and Indiana Bridge

All loads and resulting stresses given in tons of 2000 lbs. All material steel unless otherwise marked. In spans where iron is used, iron marked I, and steel S.



Data for Loads

TRUSS PANEL LOADS ASSUMED ON TOP CHORD
5 14.0 73.5 13. 13 13. 13.

" " " " " BOTTOM "
20. 19. 18.5 18. 17.5 17. 17.0 17.0 16.5 16. 15.5 15.0

ASSUMED DEAD LOADS TOP CHORD
5. 7.5 5. 2.5 2.5 2.5 2.5

" " " BOTTOM "
5 7.75 15.25 7.75 12.75 10.25 10.25 10.25 10.25 7

Live Load for all spans. on Highway, a uniform of 0.6 tons per lin. ft. of bridge.
on Railway, a train load of 1.12 tons per lin. ft. of track
with two excesses of 29.2 tons each 60 ft. apart.

...gram Kentucky and Indiana Bridge

...ll material steel unless otherwise marked. In spans where iron is used, iron marked I, and steel S.

PLATE XVIII
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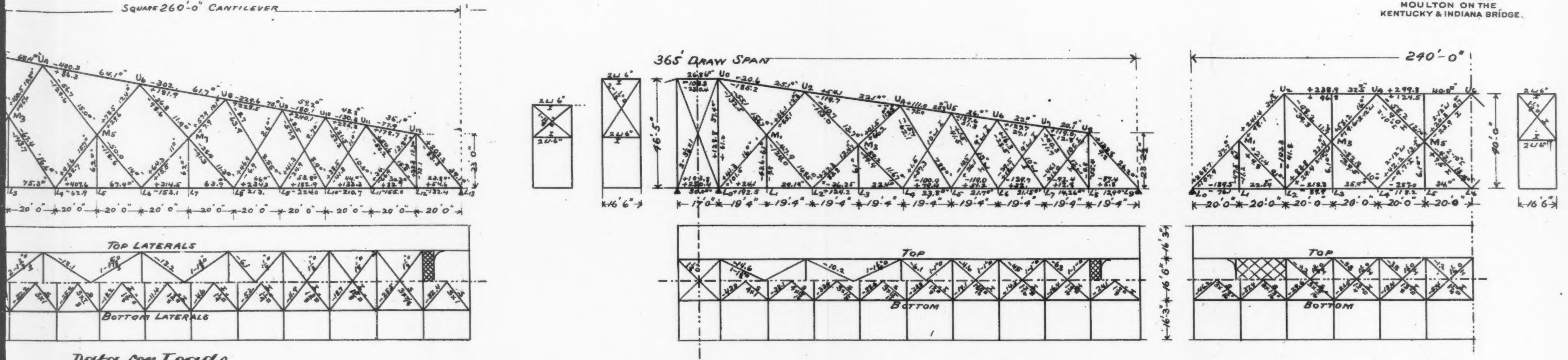
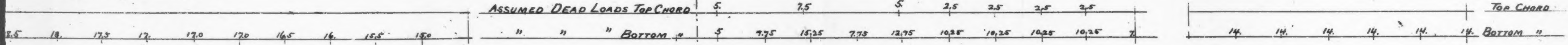


Data for Loads



on Highway, a uniform of 0.6 tons per lin. ft. of bridge.
on Railway, a train load of 1.12 tons per lin. ft. of track
with two excesses of 29.2 tons each 60 ft. apart.

PLATE XIX
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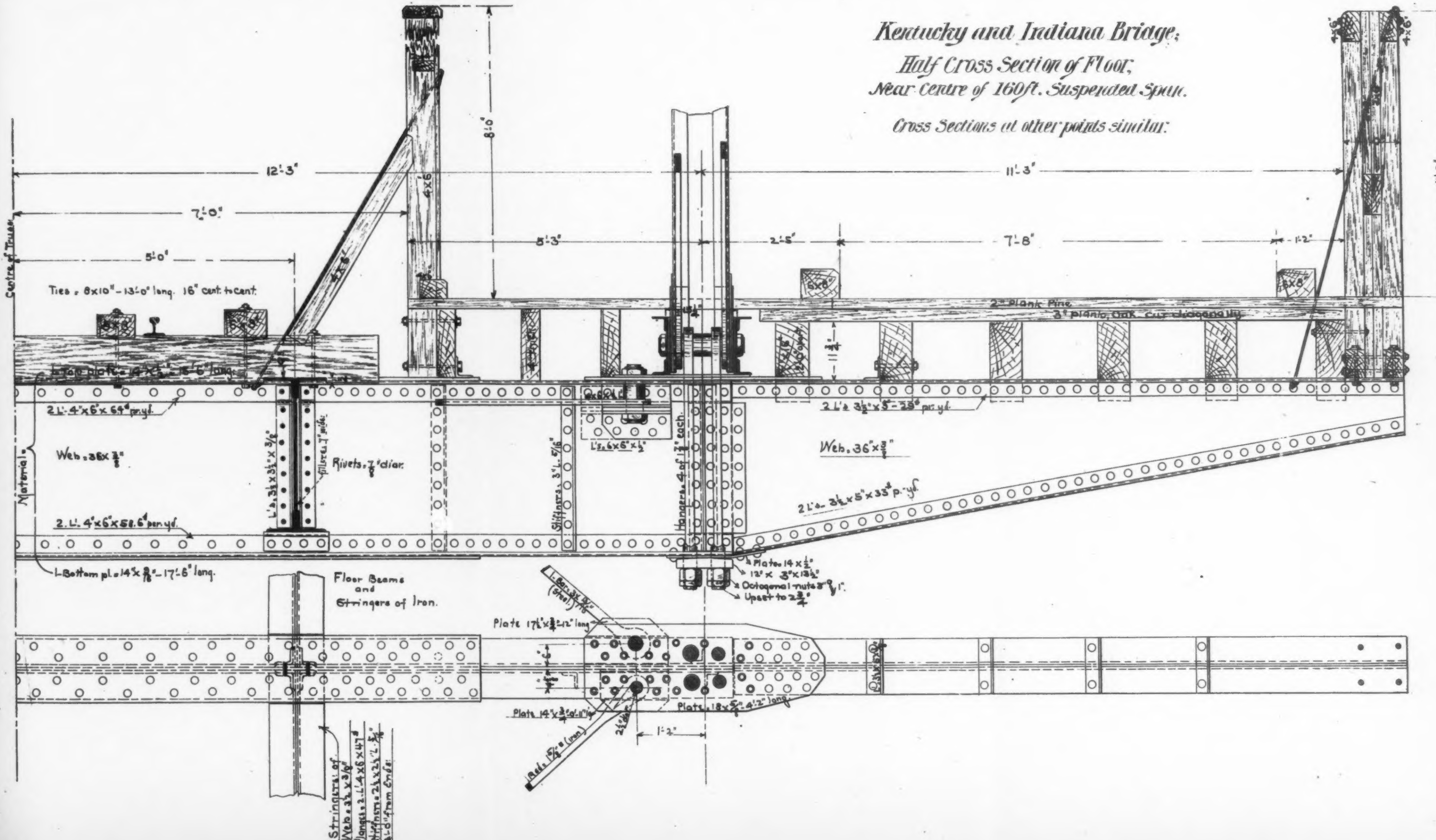

PLATE XX
TRANS. AM. SOC. CIV. ENG'RS.
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MOULTON ON THE
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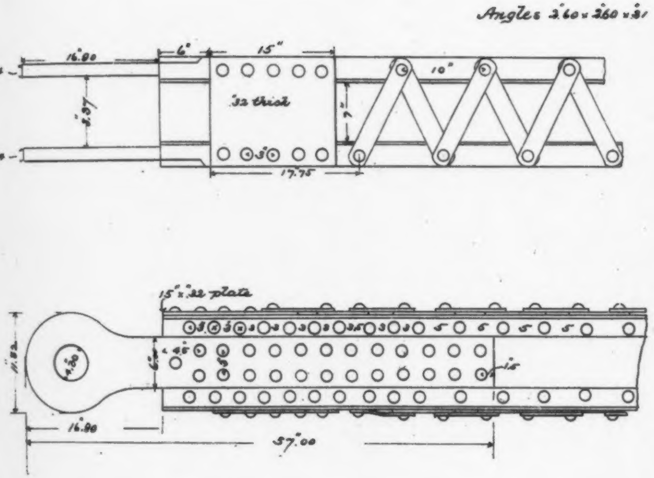
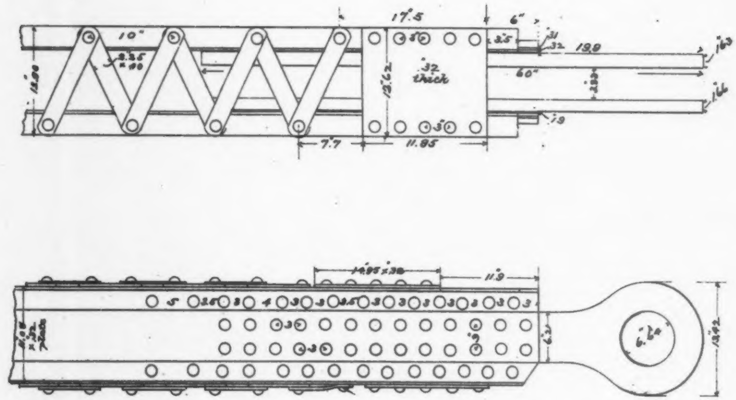
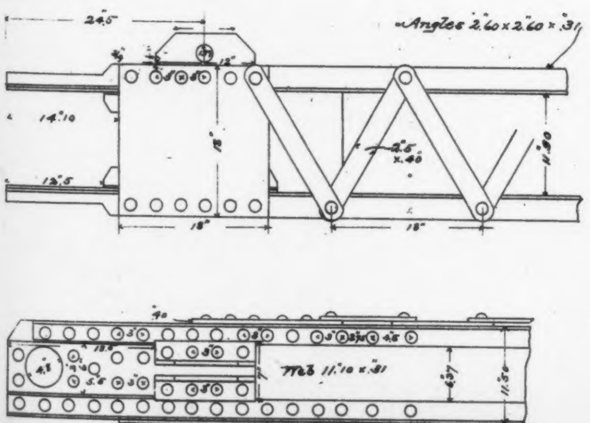
No. 4217 End A.



No. 4217 End B.



No. 4218 End A.



No. 4218 End B.

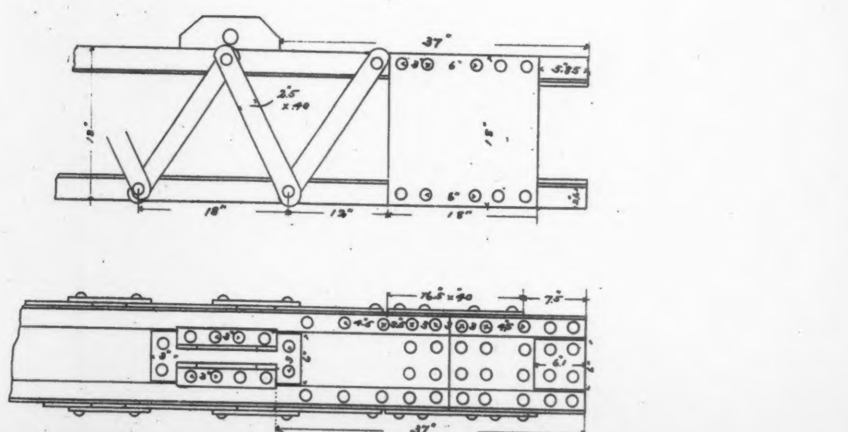


PLATE XXI
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